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MISSOURI

BOTANICAL GARDEN.

SEVENTEENTH ANNUAL REPORT.

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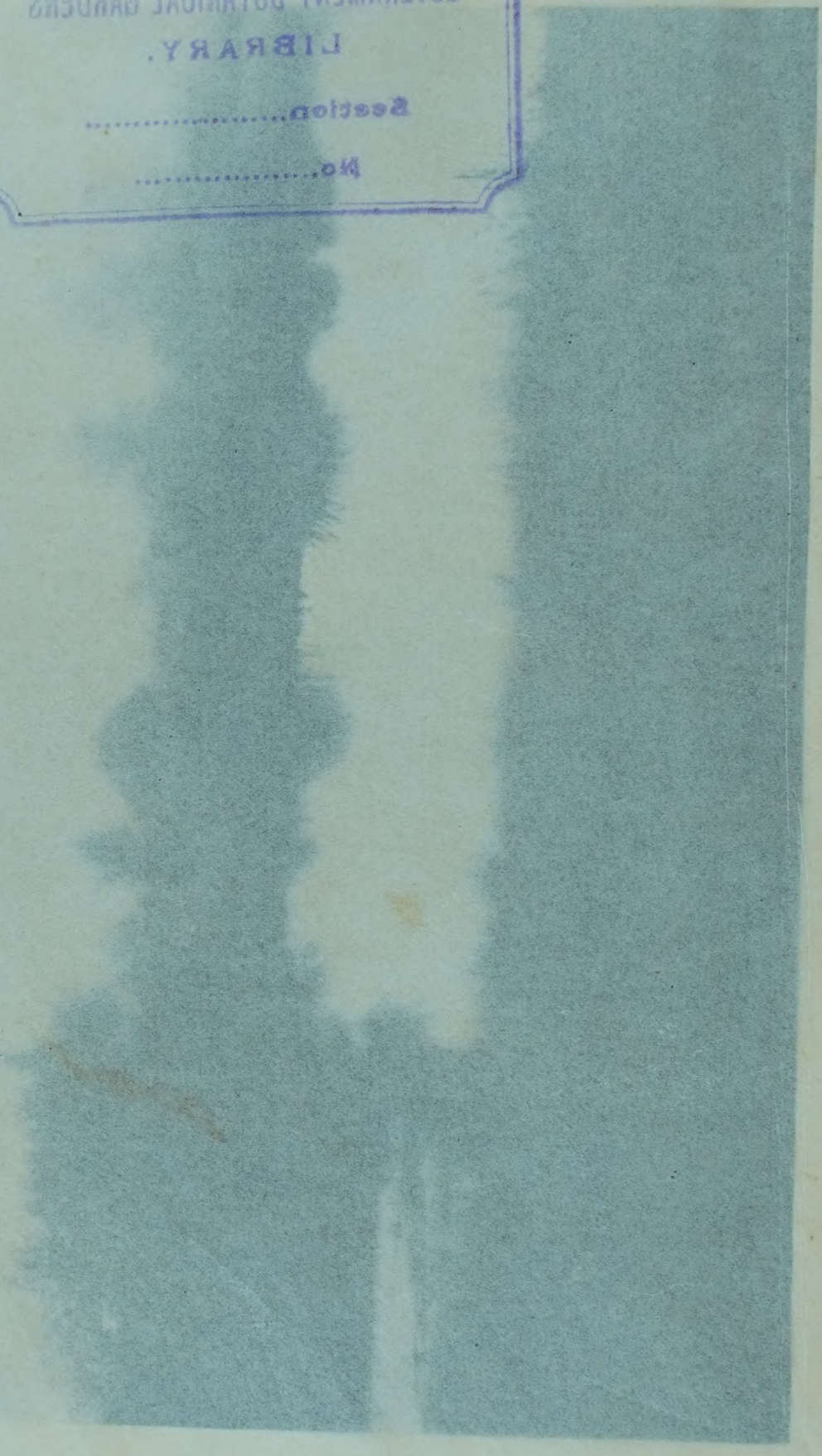

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ST. LOUIS, MO.:
PUBLISHED BY THE BOARD OF TRUSTEES.
1906.

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Bishop of the Diocese of Missouri.*

ROLLA WELLS,
Mayor of the City of St. Louis.*

A. D. CUNNINGHAM, Secretary.

**Ex-Officio.*

[1] Elected President of the Board of Public Schools of St. Louis, October 9, 1906, to succeed Robert Moore, who had held that office for one year.

PREFACE.

Under direction of the Board of Trustees, the seventeenth annual report of the Missouri Botanical Garden is presented to the public.

The sixteenth volume was issued on May 31st, 1905, which is to be regarded as the date of publication of the scientific papers it contains, except that by Professor Hitchcock, separates of which were distributed on March 29th, 1905.

These reports are sent to scientific institutions and journals in exchange for publications or specimens desirable for the Garden, and, when possible, reprints of the botanical articles they contain are presented to botanists occupied with a study of the subjects they refer to. Any of the Garden publications not out of print may be purchased at approximately the cost of publication from Mess. R. Friedländer & Sohn, Berlin, Germany; W. Wesley & Son, London, England, or the undersigned.

WILLIAM TRELEASE.

ST. LOUIS, MO., October 10, 1906.

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ALONG THE BROOK.

REPORTS FOR THE YEAR 1905.

REPORT OF THE OFFICERS OF THE BOARD.

SUBMITTED TO THE TRUSTEES JANUARY 10, 1906.

To the Board of Trustees of the Missouri Botanical Garden:

This report marks the close of the sixteenth calendar year of the Board's administration of the Missouri Botanical Garden and of the revenue property devised for its support.

PURPOSES.

The General Assembly, by an act approved March 14, 1859, authorized and empowered Mr. Henry Shaw to convey certain real estate and personal property to Trustees, for the establishment of a perpetual fund for the support of the Missouri Botanical Garden, to be maintained for all time for the use and enjoyment of the public, and as a means of education and research in botany, horticulture and allied sciences.* Fuller details of Mr. Shaw's purposes are contained in his will.†

TRUSTEES.

Mr. Shaw died on the 25th of August, 1889, and his will was admitted to probate on the second of September of the same year. As Trustees, he designated "M. Dwight Collier, Henry Hitchcock, Wm. H. H. Pettus, Dr. John B. Johnson, Adolphus Meier, Wm. G. Eliot who is now Chancellor of the Washington University, and his successor in office, Charles F. Robertson, who is now Bishop of the

* Rept. Mo. Bot. Gard. **1**: 26.

† Rept. Mo. Bot. Gard. **1**: 29.

Episcopal Church of the diocese of Missouri and his successors, David F. Kaime, James Yeatman, Judge Saml. Treat, Joseph W. Branch, Gerard B. Allen, Rufus Lackland, Judge G. A. Madill, the President for the time being of the Public Schools, and his successors in office, the President for the time being of the Academy of Science of St. Louis, and his successors, the Mayor of the City of St. Louis and his successors in office, Dr. Asa Gray of Cambridge, Massts., and Profr. Spencer F. Baird, Secretary of the Smithsonian Institution, Washington City. The two last named as honorary Trustees are added to the trust in recognition of their scientific eminence and ability."

Both of the honorary members, as well as the Chancellor of the University and the Bishop of Missouri, had died before the composition of the Board was made known by the publication of Mr. Shaw's will, as had Mr. Allen and Mr. Meier of the personally designated members. By direction of the courts the membership of the Board was therefore fixed at fifteen, comprising the ten then living designated members and five *ex officio*. Organization was promptly effected by a majority of the members thus constituting the Board, Mr. Lackland being chosen President — to which office he has been re-elected each year, and Mr. Pettus acting as Secretary for a short time until provision was made for the regular employment of a Secretary, when Mr. A. D. Cunningham was appointed to that office — which he has since held.

The Board were promptly put in control of the Garden and revenue property, and assumed their responsibility as Trustees from the nominal date of September 1, 1889. One of their first acts was to secure care for the Garden by the appointment of a managing Director for it, Mr. Shaw's selection of Professor William Trelease of Washington University being confirmed and the duties of the Director being defined as "the duties prescribed for that office in the last will of Henry Shaw, deceased, and such

other duties as may from time to time be prescribed by this Board in pursuance of the trusts declared in said will."

Of the original members of the Board appointed as individuals, only three remain in office, Mr. Lackland, Mr. Kaime and Mr. Pettus. Mr. Collier resigned in 1889 because of removal from the city. Judge Treat, because of his advanced age, retired in 1890. Mr. Yeatman and Judge Madill died in 1901. Mr. Hitchcock, who from the first had been Vice-President of the Board and Chairman of its Garden Committee, died in 1902, and Dr. Johnson and Mr. Branch died in 1903. Vacancies were filled for a time by Dr. George J. Engelmann, — elected in 1889 to succeed Mr. Collier, and resigned because of removal from the city in 1895, and Mr. George S. Drake, — elected in 1890 to succeed Judge Treat, and resigned in 1895. Membership in the Board is now held further by Mr. Leonard Matthews, — elected in 1895 to succeed Mr. Drake, Dr. John Green, — elected in 1896 to succeed Dr. Engelmann, Mr. John F. Shepley, — elected in 1901 to succeed Mr. Yeatman, Mr. Edwards Whitaker, — elected in 1902 to succeed Judge Madill, Dr. D. S. H. Smith, — elected in 1902 to succeed Mr. Hitchcock, Mr. George C. Hitchcock, — elected in 1903 to succeed Mr. Branch, and Mr. Edward C. Eliot, — elected in 1903 to succeed Dr. Johnson.

Bishop Tuttle, who had succeeded the late Bishop Robertson before the organization of the Board, is the only *ex officio* member who has met with it continuously from the first. Mr. Chaplin, who became Chancellor of Washington University in 1891, has served since that time as a member of the Board. A number of well known gentlemen have further found place on it, from time to time, while serving as Mayor of the City, President of the Academy of Science or President of the School Board.

INCOME, TAXES.

When the Trustees were charged with their duties the revenue property was appraised at $1,241,274.00, — much of it being unimproved real estate, yielding little if any revenue and burdened by taxes which year by year have become more oppressive. By gradual increments the gross rents have grown 32½%, from $91,258.32 in 1890 (when the general taxes were $22,470.53) to $120,742.94 in 1905, the general taxes meantime having increased to $36,397.57, or 62%, — nearly double the percentage increase in rents.

Special street and sewer taxes average $10,075.75 per year for the entire sixteen years, in addition to unusual large expenses for sewer and street improvements, averaging $47,360.05 for each of the last two years. The average annual cost of insuring the revenue property and keeping it in suitable repair has amounted to $12,940.94. Commissions and necessary legal and other occasional expenses have averaged $2,336.75, and the office expenses of the Board average $5,000.00, per year, — leaving an average net income, nominally available for the purposes of the Garden, of $52,261.85. Out of this, however, no less than $137,384.22, an average of $8,586.10 per year, has of necessity been reserved and has been ultimately entirely spent for street and other purposes apart from the Garden itself, to which the remainder, except for special bequests, has been devoted for improvement or maintenance.

TESTAMENTARY CHARGES.

The testamentary provisions of the founder of the Garden constituting fixed charges on the revenue are: (1) Maintaining a net income of $3,500.00 from property deeded during his lifetime to Washington University for the support of the School of Botany; this has resulted in

WITHOUT THE WALLS.

an average payment of $1,272.60 per year. (2) The sum of $1,000.00 per year for a banquet to the Trustees of the Garden and invited guests, the average expenditure for the past sixteen years being $948.56. (3) For a banquet to the gardeners of the institution and invited florists, nurserymen and market gardeners, $400.00 per year, of which an average of $368.15 has been used. (4) For premiums or prizes to be offered at a flower show held in St. Louis, $500.00 per year, the expenditure averaging $360.75. (5) For a sermon to be preached each year on the wisdom and goodness of God as shown in the growth of flowers, fruits and other products of the vegetable kingdom, $200.00 per year, which has been paid in full.

REAL ESTATE IMPROVEMENTS.

Among the real estate improvements made by the Board, in addition to sharing in general street and sewer development, is to be noted particularly the improvement of Flora Avenue, by which the main gate of the Garden is approached from Grand Avenue. This street, nearly a mile long, with the co-operation of other persons owning property along it, has been converted from a narrow dirt road into a wide macadamized boulevard with granitoid walks, shade trees, and a well planted park strip down the center, the expenditure of the Board on it amounting to $44,840.78.

UNPRODUCTIVE PROPERTY.

It has been found impracticable to carry out Mr. Shaw's plan of long term residence leases for the unimproved real estate in the vicinity of the Garden, and the courts have granted to the Board power to sell this property, on condition that the proceeds shall be reinvested so as to yield an income for the maintenance of the Garden. Under this permission some sales of building sites have been made and

the Board hope gradually to sell all of the better class of this property at a fair valuation; but much of the land is so situated with reference to railroads and the factories, etc. that have clustered along them as to have little prospective value for residences, while, as has been said, the taxes on it are becoming heavier each year. The Board are therefore being forced to the conclusion that this part of the endowment real estate must sooner or later be parted with as a whole, and the proceeds reinvested in property of a better description, capable of yielding revenue. Upon this conversion of the entire endowment into revenue-producing property obviously rests the sole hope of the Board to meet the Director's wishes — which they share — for a much needed addition to the buildings used for the Garden office, library, herbarium and laboratories, for additional and larger plant houses to relieve the overcrowding of the present collections so that they may be better displayed and suitably enlarged, for further extension of the grounds according to plans already prepared, and for the development of the institution into the great and productive research center planned by the Director in accordance with the wish of Mr. Shaw, — the realization of all of which, however, is believed to be only a question of time.

THE PARK STRIP.

When Mr. Shaw presented land to the City for the establishment of Tower Grove Park, he deeded with it a strip 200 feet in width entirely surrounding this park, except for the necessary entrance ways, with the provision, agreed to by the City, "that the Board of Commissioners of Tower Grove Park shall from time to time cause to be leased the said strip of land of 200 feet in width surrounding said park, in convenient lots not to exceed 200 feet in front, nor less than 100 feet in front, to any one person for periods of thirty years before renewal, for the purpose

of erecting villa residences thereon only; and all the gross rents received from said leases, without deduction, shall be forever paid over to said Henry Shaw and to his heirs, executors, administrators and assigns, so that he and they shall forever enjoy said rents; and said city shall execute the proper leases therefor, which shall contain a clause that there shall be only one residence on each tract so leased." The purpose was distinctly stated to be to make of the 200 foot strip about the park not only a source of ornament to the park but a source of revenue for the maintenance of the Garden. A small portion of this strip, adjoining the north gate of the park, was subsequently released by Mr. Shaw to the City as a building site for a residence erected for the superintendent of the park. When the Board assumed charge of the Garden property it was found that a few houses for park employees had been erected, at Mr. Shaw's expense, on the strip, and the rental from these was turned over to the Board; but these unsightly buildings have all been removed by direction of the Park Commissioners and, with the exception of the small temporary rents referred to, no revenue has yet been secured from this portion of the revenue endowment of the Garden. The Trustees should as early as possible take steps either to derive such income as may be secured by having the park strip used in the manner described by Mr. Shaw in his deed of gift, or to induce the City of St. Louis to lease or purchase by condemnation the entire strip surrounding Tower Grove Park, and thus enable the Board to realize from it an income for the maintenance of the Garden.

GARDEN IMPROVEMENTS.

At the Garden itself, the Board are pleased to note constant and great though necessarily expensive change for the better, and its valuation, with permanent improvements, has nearly doubled, having increased from the

original appraisal of $125,160.00 to $227,185.94. When the property came under the charge of the Trustees it was a country home on which for some years inadequate expenditure had been made for maintenance. The streets about it were without sidewalks, and the walks within were of such construction as to be impassable in wet frosty weather. The surrounding walls were crumbling, the plant houses were limited in capacity, of antiquated and inadequate construction, and very badly out of repair, while the residence assigned to the Director was found by a committee of physicians to be in a most unsanitary condition and a little museum that had been maintained for many years had so deteriorated under the care of household servants that the Director was advised to close it. The provision of room for administration, library, herbarium and research purposes also confronted the Board as an immediate necessity, as did provision for a supply of city water, improvement of existing temporary sewers, and some arrangement other than open grates for heating the residence and museum building.

On these needed improvements the Board have been compelled to spend large sums of money. The full length of the Garden front on Tower Grove Avenue has been terraced, provided with a granitoid sidewalk and planted to an avenue of maples, — already becoming beautiful and yielding in summer a pleasing shade, — while cinder paths have been maintained along the Shaw Avenue and Magnolia Avenue sides; the larger of these improvements costing $3,087.56. The principal walks of the Garden have been suitably remade; the expenditure for this and the replacement of much of the brick edging amounting to about $3,000.00. The gate-house, walls, and fences were put in repair at a cost of $5,056.03. The area covered by plant houses has been more than doubled, at a cost of $29,608.45 — the new houses being of modern construction, except for two small temporary structures, and permitting the growth

of plants that could not otherwise have been cultivated. Granitoid ponds, steps, etc., needed for the replacement of decaying old wooden structures, or to furnish opportunities for growing such plants as the Amazon lily, have cost $1,931.26.

At the Director's residence the temporarily built, unsanitary and discordant east wing was replaced in 1890 by a conveniently planned wing, at a cost of $19,000.00. A water supply, including necessary piping along Tower Grove Avenue, supplemented by a provisional sewerage system, necessitated the expenditure of $4,589.10.

In compliance with an express direction of Mr. Shaw's will for the provision of a cottage to be occupied by a person charged with caring for the mausoleum and its surroundings, a neat building has been erected which also serves as a gate-house for the private gate at Cleveland Avenue by which the Director's residence is reached from the street. The cost of this improvement was $4,538.05.

Under another provision of Mr. Shaw's will, requiring its ultimate reconstruction on Tower Grove Avenue in some convenient situation in contiguity to the Garden, his former city residence was removed in 1892 from the corner of Seventh and Locust Streets and rebuilt, mainly in fire-proof construction, in the Garden, on Tower Grove Avenue between Shenandoah and Botanical Avenues, the large expenditure of $33,478.89 for this purpose being made by direction of the court. In connection with the renovation of the residence and the removal of this building, which for the time afforded adequate room for the office, library and herbarium, a boiler pit was provided at a safe distance, from which steam heat is supplied to the office, residence, and museum buildings; $1,204.07 having been spent for this purpose in addition to subsequent improvement charges.

Among the provisions in Mr. Shaw's will, explained in some detail in certain manuscript suggestions not made a

part of that document, was one looking to the education of a limited number of garden pupils, to be lodged conveniently for their work. For this purpose a small building at the southeastern corner of the Garden, found to be in very bad repair, was renovated as far as possible and suitably furnished; the cost of this being $1,933.25.

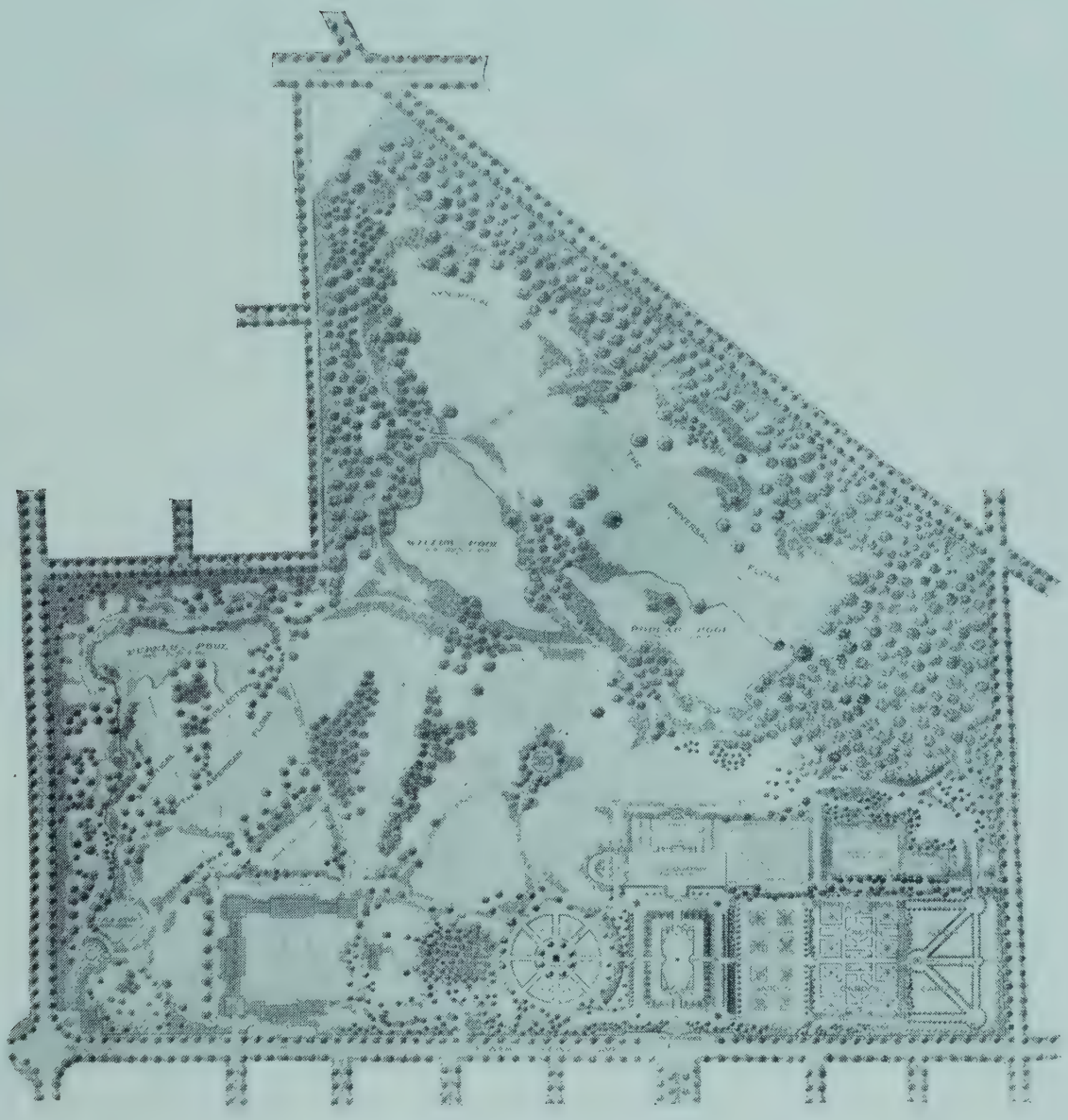
STORM AND FIRE LOSSES.

The foregoing represent the larger items of construction and improvement that it has been found imperatively necessary to make. Several hail and fire losses have been met, from time to time, amounting to $3,988.97. In 1896 the Garden suffered severely from the tornado which did such great damage generally in the City, and the Board were compelled to spend $4,479.36 in making such repairs as were possible, though a complete renovation of the Garden would have necessitated almost entirely clearing and replanting its wooded parts.

EXTENSION.

In connection with the tornado damage attention was directed to the need of general plans along which the grounds might be harmoniously and adequately improved and enlarged. The preparation of such plans was entrusted to Messrs. Olmsted, Olmsted & Eliot, whose final report has been adopted for the future development of the property at such times and in such degree as the Board may find expedient. The total expenditure in connection with these plans has amounted to $5,037.75. Acting on the advice of the landscape architects, the Board, in 1897, purchased, at a cost of $10,000.00, a narrow triangular strip of land containing $2\frac{1}{3}$ acres, needed to square the property out to Alfred Avenue.

In accordance with the plans which have been prepared,



IMPROVEMENT PLANS.

the southern extension of the grounds as so enlarged, limited by Tower Grove, Magnolia and Alfred Avenues, has been graded, drained and supplied with water pipes, and planted with a collection of about 1,400 species of plants, forming a synopsis of the North American flora, which is soon to be opened to the public. The cost of this addition, aside from the land purchased, has been $21,286.34, — of which $9,045.99 was for grading, $3,116.66 for the water supply, $2,900.00 for drains, and the remainder for planting and minor improvements.

GARDENING.

On the maintenance of the Garden, including ordinary improvements, an average of $43,675.33 a year has been spent. Of this, an average of $23,271.39 is for wages of gardeners and laborers, repairs and supplies, fuel, water, additions to the living plants, and other similar gardening purposes. The annual expenditure on the Garden office, including salaries of the Director and Superintendent, averages $5,217.67. The Board have acquiesced in the Director's belief that it is impossible for the Garden to stand still, and provision for maintenance has therefore been on a basis permitting rather small but continuous development from year to year.

By the addition of the North American Synopsis, the area of the grounds has been enlarged from 44.7 to about 65 acres, or nearly one-half. In 1889 the plant houses covered 14,840 square feet of ground; they now occupy 30,740 square feet, an increase of 107%. Propagating frames have been increased from 2,200 to 5,750 square feet, or 161%. It has been estimated that not over 2,000 or 3,000 kinds of plants were cultivated at the time when the Board took charge of the Garden. In 1895, after an accurate system of recording plant accessions had been introduced, the number of species and varieties was inventoried at 3,921, exclusive

of, perhaps, 1,000 annuals. In 1898 a new inventory showed the presence of 8,009 kinds; the inventory of 1903 showed that there were then 11,357, and the number now reported is 15,976, — an increase of 431 % over the larger of the estimates for 1889. Several of the special collections of plants are among the largest of their kind in the world. This is especially true of the cacti, comprising 678 named species representing 17 genera, and of the agaves and yuccas. The collections of palms and sago plants are also unusually large. From almost nothing, the collection of bromeliads, or plants of the pineapple family, has grown to 204 species. Orchids, of which originally there were few, and though two-thirds of the collection were destroyed by fire a few years since, have been recollected to the number of 942 species representing 116 genera, and an expert dealer in plants of this group has recently spoken of the Garden collection of orchids as being the largest in the United States. With this increase in the variety of living plants, their scientific value has been constantly raised by the incorporation of specimens collected in their native homes by the Director, who has visited Mexico and Central America for this purpose, and by others, thus permitting a definite record to be kept of their origin, — which is not usually true of purchased plants.

One of the early provisions made by the Board was for the adequate labeling of the plants, — a need specially mentioned in Mr. Shaw's will; and the entire large collection is now provided with names as far as the state of maturity of the specimens makes this possible. With the greatly increased variety and the accurate naming of the plants they are better cared for than formerly and their decorative use has received greater attention. The former promiscuous beds of flowers have given place to well set instructive groups of attractive species. As an example of this may be mentioned the recent solid planting of the sunken garden in front of the gate with beds of tulips

for the spring and of foliage plants in summer, producing an unrivaled display of the best varieties of these plants. A collection of decorative species that are hardy in this vicinity occupies a separate section of the central part of the grounds, and the names of these plants are frequently noted by visitors for use in planting their own gardens. For the convenience of teachers and classes, several hundred instructive plants are arranged in botanical sequence, and forage plants, savory herbs and medicinal plants are similarly grown in separate groups. One of the features of the Garden for several years past has been the growth through the summer of chrysanthemum plants for display in the fall. Notwithstanding the limited space available for this purpose, the chrysanthemum show of the Garden has won recognition as a competitor in attractiveness with the florists' show held in the city, and visitors who have traveled largely characterized that of this year as the finest they had ever seen — not even excepting those of Japan.

VISITORS.

The number of visitors to the Garden varies so greatly from year to year, especially as affected by fair or unpleasant weather on the two Sunday afternoons on which the Garden is opened by direction of Mr. Shaw's will, that it is hard to furnish comparative figures. Until the middle of 1898 only estimates were made: since then a regular count has been kept. In 1904, the World's Fair year, the visitors numbered 316,747. The average from 1899 to 1903, was 83,503. In 1905 there were 100,830. The visitors on the open Sundays average a little over a fourth of the yearly total.

Though the number of visitors is evidently increasing, it is a matter of regret that more of our citizens do not avail themselves of the privileges given by Mr. Shaw's bequest, and that so few seem to know that, excepting

Sundays and holidays, the Garden is always open to everybody, and free of all charge.

LIBRARY.

The provision of a library and herbarium for purposes of scientific research, in addition to the maintenance of a beautiful and instructive garden, are among the designated purposes of the founder of the Garden.

A small but good nucleus of a botanical and gardening library came into possession of the Trustees when they assumed charge of the property. To this the special libraries of the late Dr. George Engelmann and of the Director, and, later, the collection of early books of the late Dr. E. L. Sturtevant, have been added by gift. Further smaller gifts have been received every year, and purchases have been liberally made, a yearly average of $4,418.82 having been spent on the library, including salaries, fuel, purchases and binding. From somewhat less than 5,000 numbers, the library has thus been brought to a present total of about 51,000 books and pamphlets, — a tenfold increase. It is now justly ranked as the foremost botanical library in the country, and compares favorably with the great libraries of the Old World. Its present valuation is $84,248.35.

HERBARIUM.

In the same manner, the Bernhardi and Riehl herbaria, bought by Mr. Shaw and numbering about 60,000 specimens, were almost immediately added to by the gift of the invaluable Engelmann herbarium, of nearly 100,000 specimens; and gifts, exchange and purchase have further brought the number of specimens of dried plants at the Garden up to a present total of about 524,000, — eighty-seven times the original number. On the herbarium, an average of $2,531.91 has been spent yearly, for salaries, fuel and purchases; its present valuation is $79,216.75.

INSTRUCTION IN GARDENING.

The requirement that instruction in gardening and horticulture should receive attention at the Garden, in addition to the provision of a lodging house for pupils, led to the entire renovation of the fruit orchard some years ago, at a cost of $444.44, and two small vegetable houses have been built for further experimental and educational use. The annual expenditure on the gardening course averages $930.34.

The Director reports that of the 39 pupils thus far enrolled, of whom 15 completed the course, ten are now successful florists or gardeners, two have become landscape architects, three hold responsible park positions, two are college horticulturists with teaching as well as practical duties, one is a surveyor, one is a government plant experimenter, and one is a forester in the Philippine service.

INSTRUCTION IN BOTANY.

Mr. Shaw's provision for a close connection between the School of Botany, which he had endowed in Washington University, and the Garden has been of great assistance to the undergraduate department of the University, and through the Garden opportunities for work have been offered to graduate students of whom five have received the Master's degree and six the degree of Doctor of Philosophy with botany as a major study. The Board expect to see a large increase in this utilization of the Garden facilities commensurate with the very gratifying growth of Washington University. Indirectly the Garden has been of much use to the young men who have served as assistants in its office, library or herbarium, or as teachers in the school of botany, for with very few exceptions they have gone to college, government or other positions of high

responsibility in botany or horticulture, for which their service here gave excellent training.

RESEARCH AND PUBLICATION.

Repeated mention is made in Mr. Shaw's will of his purpose to have scientific research, no less than decorative gardening and botanical and horticultural instruction, included among the activities of the Garden. Details of administration have been left necessarily to the Director in consultation with a special Garden Committee of the Board, but his purpose to develop the institution symmetrically under the broad plan of its founder has always met with the support of the Trustees, who have approved his policy of not only allowing but expecting a part of the time of capable employees to be spent in investigation. Though he looks forward hopefully to the time when the revenue of the Board shall permit the employment at the Garden of a corps of highly trained and expert investigators giving a large part of their time to such study, he has been able as yet to devote to this work only a small part of the time of otherwise indispensable employees, the salary apportionment and incidental expenses for this purpose averaging $1,000.83 per year, for the last 12 years. He therefore points with pride — and the Board share his gratification — to the fact that under existing conditions not a year passes without the accomplishment of valuable research work at the Garden, and that its publications win commendation for their useful contents as well as for the attractive and convenient form in which they are brought out and the liberal conditions on which they are furnished to botanical libraries and investigators everywhere. The yearly cost of publication, including reissues of some of the volumes from electrotyped plates which are preserved, has averaged $2,000.37, but the Garden's Reports have given it a standing in the scientific world that it could have attained in no other way, and by far the largest part of the gifts to the

A TANGLE OF MOONSEED.

library and herbarium — averaging $1,775.36 per year for the past 13 years — are received in exchange from correspondents to whom the Reports are sent.

EXCHANGES.

Though already planted and partly equipped, the Garden was without scientific affiliations when its development was entrusted to the Board. To bring it into exchange relations with other establishments, the publication of these annual volumes, devoted to administrative reports, scientific monographs, etc., was early decided on. Through the medium of this publication the Garden now stands in exchange relations with 859 institutions interested wholly or in part in botany, gardening, horticulture or forestry. The exchange of plants and seeds with other gardens has recently been greatly increased by the issuance of an annual exchange seed list which is sent to the officers of such establishments, who may thus readily ascertain and request such of their desiderata as can be furnished. The first seed list included 813 species, and the list just issued contains the names of nearly 1,400 kinds of plants of which seeds were saved for exchange purposes in 1905.

POLICY OF ADMINISTRATION.

Through its entire history under the management of the Board the Garden has been treated as a public institution in the fullest and most liberal meaning of the term. None of its Trustees receive any form of remuneration for their services. It is not managed as a source of revenue. Such of its publications as are sold are charged for at cost. Its employees, who are always required and ready to render any proper service in their power, are forbidden to accept fees. The office staff devote a large part of their time to examining into and reporting on questions put in connection with a large correspondence or asked by visitors.

The library and herbarium are opened to any one capable of using them, and books and specimens are freely loaned to responsible students thus enabling an increasing number of persons to make scientific use of the Garden facilities each year without incurring the expense of a visit to St. Louis. Above all, restrictions on visitors are limited to the few simple rules necessary to preserve the property and insure its pleasant and profitable use by all.

FINANCIAL REPORT FOR 1905.

We submit now for your consideration the financial results for the year ending December 31st, 1905.

Our rental receipts show an increase of only $521.34 over the previous year, a few vacancies in the early part of the year interfering with an anticipated increase; but as all properties are now occupied we may hope for an increase of at least $5,000.00 over last year.

We have disposed of 220 feet on Flora Boulevard for a total sum of $17,510.00.

The Board deemed it wise to dispose of a piece of property at the northeast corner of Seventh and Chestnut Streets fronting 21 feet on Chestnut, for the sum of $100,000.00, it having been under lease for 89 years at $3,700.00 per year; we hope to invest the proceeds in real estate yielding a greater income.

We have purchased a piece of property 70×70 feet on the north side of Poplar Street between 12th and 13th Streets, adjoining property already belonging to the Board and improved with five small houses renting for $1,200.00 per year, for the sum of $10,000.00, for the purpose of investment.

We have again been called upon by the City for heavy special taxes for streets and sewers, amounting in all to $47,151.47, distributed as follows:

Rock Spring District Sewer No. 14	$ 7,309 24
Manchester Road Joint District Sewer	33,899 25
Rock Spring District Sewer No. 13	1,979 55
Alley in City Block No. 4947	1,164 00
	$ 44,352 04
Sundry streets reconstructed	2,799 43
	$ 47,151 47

These improvements were anticipated in our last report. Other improvements of a similar character will necessitate the following expenditures during the year 1906, and, if paid in cash, a portion of the cost must be met by sales of residence property: —

Old Manchester Road	$ 20,000 00
Shaw Avenue	16,000 00
McRee Avenue	4,000 00
Spring Avenue	14,000 00
Vandeventer Avenue	4,000 00
	$ 58,000 00

The annual bequests provided for in Mr. Shaw's will have been carried out at a cost of $1,884.11, with the exception of the Trustees' annual banquet which was not held.

No permanent improvements have been made at the Garden, but a large number of additions have been made to the herbarium, and much work has been done on the library catalogue.

The following amounts have been credited to the Stock Account: —

Library	$4,332 64
Herbarium	5,305 25

RECEIPTS.

Rentals	$120,742 94	
Interest and dividends	1,828 77	
Garden pasturage above expenses, etc.	403 04	
Garden hand-book sales	198 25	
Publication sales	4 08	
Total income collections		$123,177 08

Brought forward		$123,177 08
Sales of real estate	$100,000 00	
" " under decree of Court	17,510 00	
Insurance for loss to buildings	1,759 87	
" " " rents	20 00	
Shaw School of Botany, rent	2,850 00	
Bonds, stocks and certificates	40,000 00	162,139 87
Total receipts		$285,316 95
Cash on hand December 31, 1904		1,638 28
		$286,955 23

DISBURSEMENTS.

Garden Account,		
Labor pay-roll	$19,288 89	
Students' pay-roll	1,474 80	
Office assistance	1,683 00	
Fuel	1,839 53	
Water	234 50	
Repairs and supplies	2,638 25	
Plants and seeds	1,046 71	$28,205 68
Herbarium Account,		
Salaries	1,688 51	
Fuel	128 54	
Current expenditure	2,599 12	4,416 17
Library Account,		
Salaries	2,893 92	
Fuel	146 68	
Current expenditure	1,966 89	5,007 49
Office Account,		
Salaries	4,681 06	
Fuel	116 47	
Current expenditure	943 52	5,741 05
Research Account,		
Salaries	774 96	
Current expenditure	463 35	1,238 31
Scholarship Account,		
Instruction	723 60	
Care of Lodge	240 00	
Fuel	105 82	
Current expenditure	101 15	1,170 57
Total maintenance		$45,779 27
Garden Improvement,		
North American synopsis, plans		1,479 60
Total amount expended on Garden		$47,258 87

Brought forward		$ 47,258 87
Publication Account,		
Sixteenth annual volume	$ 2,000 00	
First " " reprint	254 85	2,254 85
Property Expenses,		
State, school, city and sprinkling tax . . .	36,397 57	
Streets, sidewalks and sewers	47,151 47	
Insurance	7,501 56	
Repairs	8,625 04	
Improvements	1,456 06	101,131 70
Office Expenses,		
Salaries	4,200 00	
Office rent	900 00	
Printing, advertising, telephone, etc. . . .	777 25	5,877 25
Bequests,		
Annual Flower Sermon	200 00	
Annual Flower Show	423 00	
Gardeners' Annual Banquet	405 30	
Washington University, School of Botany .	855 81	1,884 11
Sundries,		
Real estate	10,000 00	
Bonds, stocks and certificates	110,000 00	
Legal expenses	1,816 90	
Repairs to buildings damaged by fire . . .	1,759 87	
Shaw School of Botany, rent, etc.	2,200 00	
Commissions	477 00	126,253 77
Total disbursements		$284,660 55
Cash balance December 31st, 1905 . . .		2,294 68
		$286,955 23

Respectfully submitted,

R. J. LACKLAND, President.

Attest:

A. D. CUNNINGHAM, Secretary.

SEVENTEENTH ANNUAL REPORT OF THE DIRECTOR.

SUBMITTED TO THE TRUSTEES JAN. 10, 1906.

To the Board of Trustees of the Missouri Botanical Garden:

The following report for the year 1905, on the Missouri Botanical Garden and the School of Botany connected therewith, is respectfully submitted in compliance with the rules of the Board.

GARDENING.

Decorative gardening, from the nature and limits of the formal grounds devoted to this purpose, presents much the same problems year after year, and they are necessarily similarly met. Last year about 37,500 plants were used in ornamental bedding, an increase of some 2,000 as compared with the preceding year. The early planting of the parterre with bulbs, begun in 1904, has been repeated, and with equal success. Through the summer the same tract was devoted to a collection of coleus in masses representative of choice varieties. These new features, and the bulb and foliage bedding on either side of the main entrance-way, met with general commendation.

Among the special greenhouse collections, the succulents, palms, cycads, and orchids have attracted particular attention, and each of these has received material enlargement. Out of doors, massed economic plants from the tropics, asters, pinks and dahlias, were satisfactorily grown in more than usual number and variety. For the fortnight beginning with November 13, a notable feature of the Garden was a collection of about 2,000 chrysanthemum plants, representing 211 varieties, well grown as standards, for massed bloom, or to single heads. These were displayed under canvas, and many flattering com-

A SECLUDED WALK.

ments have been heard on the exhibition, which was viewed by about 25,000 people, — one-fourth of the visitors for the entire year.

Accessions number 314, comprising 17,620 plants or packets of seeds. Of these, 680 plants, valued at $288.45, and 360 seed packets, valued at $22.65, were collected, and 26,845 plants, valued at $1,879.15, were propagated, by Garden employees; 7,745, representing 199 of the 314 entries and valued at $645.55, were presented or received in exchange for material or for Garden publications; and 9,875, representing 67 entries, were purchased, the Secretary's books showing an expenditure of $1,046.71 for such purchases, including transportation, duty or other charges.

The records show that 2,345 species or varieties were added to the collection of living plants, while 576 were lost or discarded, leaving a net gain for the year of 1,769, and bringing the total of cultivated species up to 15,976, in contrast with the 14,207 noted for the preceding year.*

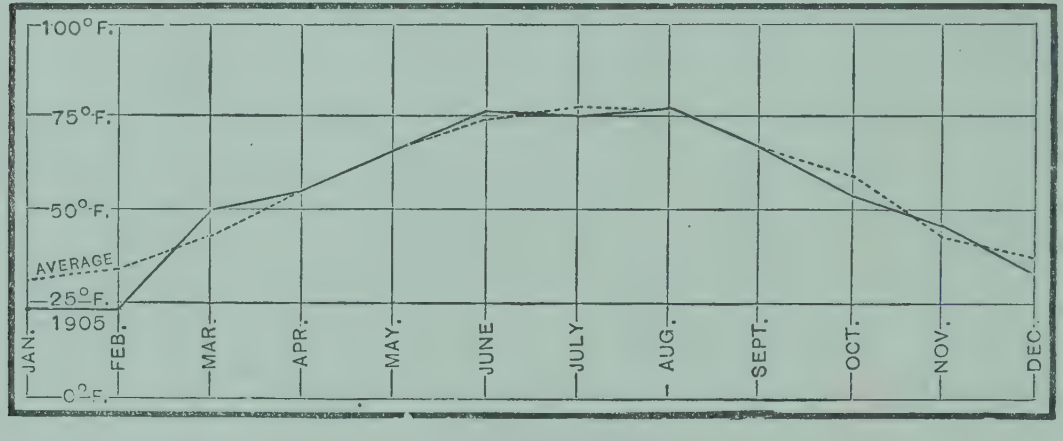
In January the Garden issued its first "exchange seed list," which included 813 species or varieties, of which about 18% were collected from wild plants of this vicinity, — the others being from Garden plants. The convenience of this list for correspondents was indicated by the receipt of greatly increased requests for seeds, so that the distribution of exchange material has been far greater than usual; the total during the year amounting to 4,173 packets of seeds, valued at $417.30, and 1,320 plants, valued at $77.80. As in earlier years, surplus bedding plants, together with many of those removed from the grounds at the end of the season, including duplicates of ferns, begonias, etc., not needed for the houses, have been given to charities and schools. The latter distribution, of some 800 plants, was effected largely through the effort of Miss

* Rept. Mo. Bot. Gard. **16**: 14.

Mary C. McCulloch, Supervisor of Kindergartens in the public schools of the city. About 300 surplus plants have also been given to High Schools and Normal Schools, to be used for purposes of instruction.

As in the preceding year, the summer of 1905 was cool. The average mean daily temperature for the entire year was 1.2° F. below the normal. The months of January and February were much colder than usual, necessitating a considerable increase in the expense of maintaining the plant houses. The entire month of March, on the other hand, was unusually warm, so that

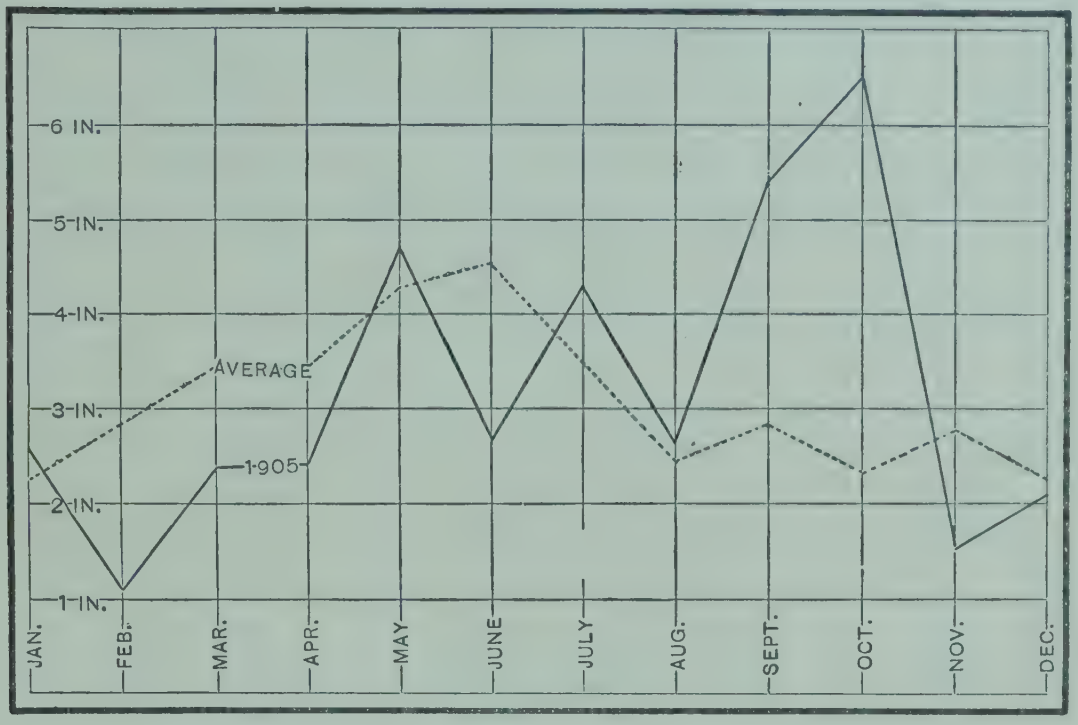
DIAGRAM A.



MEAN TEMPERATURES.

operations usually performed in April were found to be necessary in March, thus increasing the length of the open season by about a month. The precipitation for the year has amounted to 38.54 inches, in contrast with the average of 37.14 inches given by the sheets issued by the local Weather Bureau office, — from which the accompanying diagrams A and B have been compiled. In the early spring, in June and in all the cold months the precipitation was considerably below the average; but in May, July and August the average was a little exceeded and the September and October rainfall was very high. Through most of the growing season it was rather uniformly distributed,

DIAGRAM B.



PRECIPITATION.

favoring the growth of most bedding plants but also greatly increasing the labor necessary to keep the grounds free from weeds. For several reasons, therefore, the cost of gardening this year has been unusually high.

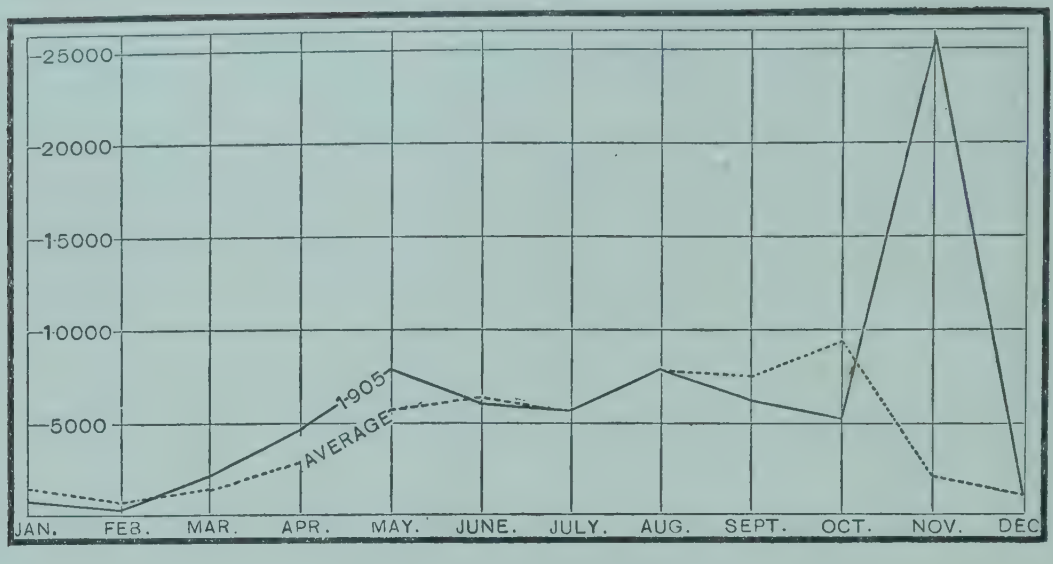
VISITORS.

The total number of visitors for the year reached 100,830, of whom 12,355 were recorded for the open Sunday afternoon in June, and 15,208 for the open Sunday afternoon in September, the remaining 73,267 being week-day visitors. Diagram C shows the distribution of the latter by months. The contrasted dotted line,—representing the average for the period covered by accurate records (beginning with midsummer in 1898) with exception of the aberrant years 1902* and 1904,†—seems to correspond closely with the normal out-door

* Rept. Mo. Bot. Gard. **14**: 17.

† Rept. Mo. Bot. Gard. **16**: 17.

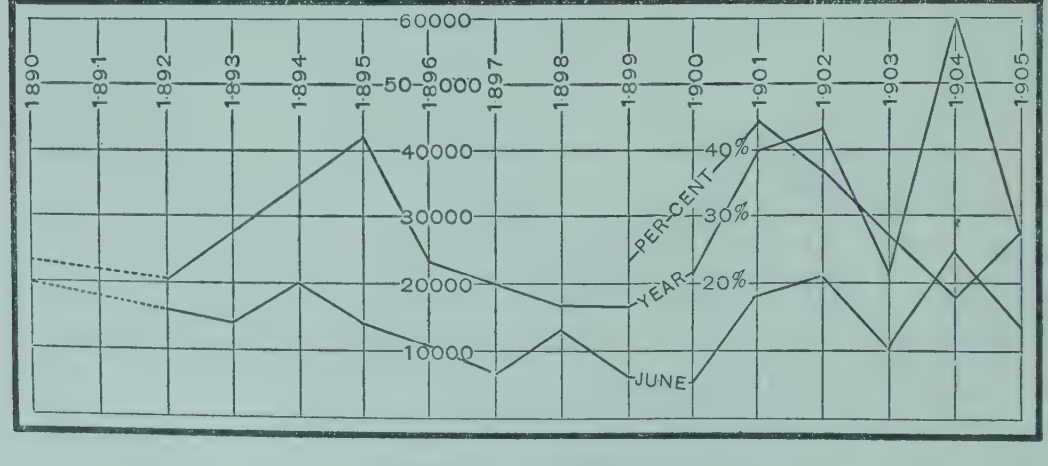
DIAGRAM C.



VISITORS ON WEEK-DAYS.

activity of our citizens. The great increase in the November visitors this season, due primarily to the chrysanthemum exhibit already mentioned, is directly attributable to the fact that the officers of the street-car company placarded the cars in such a way as to attract public attention to the Garden. Special recognition is due to the company for this effort, which resulted in mutual advantage. The relation of Sunday to week-day visitors, who this year reached 27% of the total, is graphically shown on diagram D.

DIAGRAM D.



SUNDAY VISITORS.

Among the visitors for the year, were noted 431 children brought from a neighboring city and 1,846 of our own school children, accompanied by teachers and usually guided by Garden employees. Many teachers also have visited the Garden for material for class use. This increasing use of the collections by teachers and pupils is particularly gratifying; and, in view of the dearth of nature-study material in a large city, its much larger growth is to be looked for.

Of the little Handbook of the Garden, 795 copies have been sold.

THE HERBARIUM.

The past year has been marked by unusual increase of the herbarium. Early in the season the herbarium of the late Henry Eggert was secured by purchase. This collection is especially rich in representatives of our local flora and of the flora of the Southwest. Approximately half of the specimens are already mounted and incorporated. It has also been found possible to purchase the collection, chiefly fungi, of Professor S. M. Tracy, about two-thirds of which have been mounted. Other especially large purchases are the general herbarium of Professor Bruce Fink, — some 6,000 specimens; about 5,000 plants of the Spanish peninsula collected by Dr. Michel Gandoger; 1,249 Texas plants collected by Mr. Julien Reverchon; about 1,500 Californian plants from Mr. Leroy Abrams; about 1,200 plants of the same region from Mr. A. A. Heller and a like number from Georgia collected by Mr. R. M. Harper; approximately 1,000 Californian plants from Mr. A. D. E. Elmer; a like number pertaining to the upper Rocky Mountain region, from Professor Aven Nelson; about the same number of Mexican plants from Dr. Edward Palmer; and a similar number of African plants from Mr. G. Zenker. In addition to these, the usual current collections offered for sale have been purchased and many and valuable exchange additions have been made to the herbarium.

Through the courtesy of the Directors of several foreign botanical gardens — notably those at Kew, Berlin and Palermo — and Sir Thomas Hanbury, of Ventimiglia, whose fine private garden was freely opened for the purpose, I have been enabled personally to enrich our herbarium by a valuable collection of specimens and photographs — including those of type plants — representative of the genus Agave, to the field study and collection of which I was also able to devote two months early in the year.

The incorporated additions for 1905 amount to 34,535 specimens, of which 2,783, valued (unmounted) at $139.15, were presented or received by way of exchange; 1,878, valued at $93.90, were collected by employees of the Garden; and 29,874 were bought, the expenditure for specimens and material amounting to $2,599.12.

The herbarium, so far as now mounted, consists of: —

The Engelmann Herbarium (all groups)		97,859	specimens.
The General Herbarium: —			
Higher plants.			
The J. J. Bernhardi Herbarium	61,338		
The Henry Eggert Herbarium*	18,894		
The J. H. Redfield Herbarium	16,447		
The Sturtevant and Smith Herbarium	7,446		
The Gustav Jermy Herbarium .	4,789		
The Chapman Herbarium* . .	3,536		
The Sadie F. Price Herbarium .	2,912		
Other specimens	264,158	379,520	"
Thallophytes.			
The J. J. Bernhardi Herbarium*	610		
The Gustav Jermy Herbarium .	1,659		
The S. M. Tracy Herbarium* .	4,312		
The Wm. Trelease Herbarium .	11,000		
Other specimens	28,885	46,466	"
Making a total of		523,845	"
Valued at		$78,576 75†	

* So far as yet incorporated.

† This valuation, at the rate of $15.00 per hundred mounded sheets.

IN THE NORTH AMERICAN GARDEN.

Details concerning the larger exsiccatae of the herbarium are given in my last report,* and need not be repeated here, as only small current additions are to be noted.

In addition to the herbarium and shelved or incorporated exsiccatae, the following material should be noted as of the same general character: —

Wood specimens of various sizes . .		800		valued at $ 55 00
Wood veneers.				
Spurr's cabinet of veneers from the Jesup collection		541	veneers,	
Hough, American Woods,	10 fascicles	750	"	
Michel, Feine Holzschnitte,	2 "	285	"	
Nördlinger, Querschnitte,	11 "	1,100	"	
Sykyta, Das Holz, . . .	1 "	25	"	
Tokyo Imperial Museum, Useful Woods, . . .	1 "	255	"	
Together	25 "	2,956	"	valued at $175 00
Microscope slides.				
Penhallow, N. A. Coniferae		268	slides,	
Other slides		1,583	"	
Together		1,851	"	valued at $410 00
Total valuation				$640 00

THE LIBRARY.

As in 1904, the absence of a special appropriation for the purchase of books has prevented the addition to the library of large sets, but no difficulty has been experienced in providing books needed for work in hand; considerable further progress has been made in binding serials and the like, and the exchange relations of the Garden have added the customary large representation of the current publications of learned bodies interested in botany. The librarian has also found time to increase largely the number of incorporated authors' separates, by cataloguing and shelving material already on hand in addition to current accessions.

* Rept. Mo. Bot. Gard. **16**: 21.

The additions for the year number 829 books, valued at $1,280.50, and 3,859 pamphlets, valued at $523.15, presented or received in return for Garden publications; and 475 books and 219 pamphlets bought, the expenditure for purchases and binding amounting to $1,577.14.

The card index has been enlarged by the addition of 97,676 cards, of which 79,039 were written by employees; 16,146 were purchased; and 2,491 were presented. Among the additions are many cards referring to floral ecology and to seedlings, the former subject being now represented by some 33,000, and the latter by about 28,000 cards, while the references to plant illustrations number about 190,000.

The distinct serial publications now received at the library number 1,237, of which 93 are bought and 1,144, issued by 859 institutions or publishers, are received in exchange for the Reports of the Garden. The total here reported is 13 smaller than that reported for 1904, as the result of a careful revision to date, — a considerable number of publications having been discontinued, although a number of additions have been made to the exchange list.*

As now constituted, the library contains:—

Pamphlets	29,188			
Books	22,009			
	51,197	valued at		$78,533 99
Manuscript volumes	77	"	"	910 00
Total	51,274	"	"	$79,443 99
Index cards	480,436	"	"	4,804 36
Total valuation of library				$84,248 35

During the year just closed, a special provision by the Board has enabled the librarian to begin the preparation of a list of biological serials contained in the libraries of St. Louis. Satisfactory progress has been made on the manuscript of this list, which is expected to be completed

* Rept. Mo. Bot. Gard. 16:23.

in the early part of the new year. It is believed that the publication of this list, when effected, will prove of value to the increasing number of persons who are carrying on scientific work in and near the city.

By direction of the Board, a third issue of the first Report of the Garden was made, early in the year.

RESEARCH AND THE USE OF FACILITIES.

Such time as could be spared from their immediate duties has been given to investigation by a number of Garden employees, by whom scientific papers have been published or are in course of preparation. By direction of the Board I represented the Garden in June at an International Botanical Congress held in Vienna, to which I had the honor of being further accredited as the representative of the National Academy of Sciences. In connection with this European trip a considerable amount of research work was done, — to which reference has already been made.

As in earlier years, a number of botanists have visited the Garden for the purpose of using the library and collections. It is a matter of regret that more persons do not avail themselves of its facilities in this manner, — particularly since the presence of investigators is most stimulating to the Garden staff. In compensation for this, however, — and indeed, partly accountable for it, — transcripts and photographs have been made in the library, notes taken in the herbarium, and books and specimens loaned in considerable numbers to further the work of botanists who were unable to bring their studies here; the passage of each year marks an increase in this use of the equipment of the institution.

THE HENRY SHAW SCHOOL OF BOTANY.

The teaching staff of the School of Botany has not been changed since my last report. The stated University

courses in which botany figures, each of which is based on three exercises a week unless otherwise stated, have undergone certain desirable changes,* and they are now offered as follows: —

1–2. Biology: A lecture and laboratory course devoted to the consideration of life processes as exemplified in the animal and plant kingdoms. *Two lectures and four hours of laboratory work each week throughout the year. Open to all classes.*

1–2. Botany: Elementary Morphology and Organography. Laboratory work, with supplementary lectures and quizzes, dealing with the form and structure of plants, with special reference to their life processes, including ecological adaptations, and to Systematic Botany.

3–4. Cytological Technique. Laboratory work in the cultivation and examination of bacteria and the methods of histological investigation, combined with a study of the principal types of plant anatomy — specially adapted to the needs of students intending to study medicine.

5–6. Plant Physiology, including Ecology. Laboratory work, with supplementary lectures.

7–8. Systematic Botany. Laboratory and field work, with supplementary lectures, dealing with the comparative structure and the classification of plants.

9–10. Plant Pathology and Applied Mycology. Laboratory work.

In addition to these electives, special courses are arranged for graduate or other advanced students, as need is found for them.

I am pleased to report a still further increase in the number of students taking work in the School of Botany, the enrollment for the first term of 1905–6 being as follows: — "Biology 1," 11; "Botany 1," 13; "Botany 3," 10; "Botany 5," 7, — a total of 41 students, of whom the eleven first noted give about equal time to botany and zoology, and the others are taking one full botanical course each.

At the 1905 Commencement of Washington University the degree of Master was conferred on Miss Laura L. Eames, Miss Winifred Ashby and Mr. Dean H. Rose, for work in botany. There are now enrolled in the University

* See Rept. Mo. Bot. Gard. **14**: 24. **15**: 32.

one candidate for the Master's degree, and three for the Doctor's degree, with botany as a major study.

GARDEN PUPILS.

The course in gardening and the teaching in it have remained unchanged through the past year.

On the result of duly announced competitive examination, the free scholarships reported a year ago* were awarded in March to Arno Nehrling of Gotha, Florida, and Eugene Smyth, of Topeka, Kansas. The latter tendered his resignation in July, to undertake preparation for college work, and the scholarship so vacated was then assigned to H. L. Ochs, of St. Louis, who had passed a satisfactory examination in the spring though he did not then win a scholarship. In November, Miss Eda A. Sutermeister, who for some four years has been engaged in practical landscape work which was held to be an adequate equivalent for a portion of the required manual work not done with her prior resident study, was admitted to examination and given the customary Garden certificate.

THE GARDEN STAFF.

No changes in the office force are to be reported, though the number of temporary assistants has been greater than in other recent years because of library work on the list of serials and the indexing already referred to, and of revisional work in the herbarium.

SPECIAL TESTAMENTARY PROVISIONS.

Three special events provided for by the will of Mr. Shaw have taken place in 1905, as follows: —

The annual flower sermon was preached in Christ Church Cathedral, St. Louis, on the morning of May 14, by the Right Reverend Lewis Burton, Bishop of Lexington, Kentucky.

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* Rept. Mo. Bot. Gard. 16:27.

The Gardeners' banquet was given at the Mercantile Club, St. Louis, on the evening of November 8. The Director of the Garden presided, under the provisions of Mr. Shaw's will. About ninety guests were present, among them the gardeners and office staff of the institution, representatives of the Board of Trustees, the staff of the Mississippi Valley Laboratory of the United States Department of Agriculture which has an office at the Garden, and a large representation of the floricultural, nursery and market gardening interests of St. Louis and vicinity, as well as a number of gentlemen interested in the growth of plants for public utility. Speeches were made by Mr. George E. McClure, of the Missouri Botanical Garden, who responded to the toast "The Gardener;" Mr. J. F. Ammann, of Edwardsville, Illinois, President of the St. Louis Florists' Club, who responded to the toast "The Florist;" Mr. E. A. Riehl, of Alton, Illinois, who responded to the toast "The Nurseryman;" Mr. L. A. Goodman, of Kansas City, Missouri, President of the American Pomological Society, who responded to the toast "The Pomologist;" Mr. L. C. Davis, of Old Orchard, Missouri, whose toast was "The Market Gardener;" Mr. Gerard Swope, of St. Louis, who spoke on "Public Playgrounds;" Mr. W. J. Stevens, of St. Louis, who spoke on "School and Vacant Lot Gardens;" Mr. H. C. Irish, of the Missouri Botanical Garden, Secretary of the National Council of Horticulture, who spoke on "Federated Interests;" and Mr. Henry T. Kent, President of the Civic Improvement League of St. Louis, who spoke on "General Civic Work."

The sum of $500.00 authorized for annual use in the form of premiums for a flower-show was placed at the disposal of the St. Louis Florists' Club. Their awards for authorized premiums at their exhibition, held from November 8 to 11 inclusive, were duly approved and paid.

Very respectfully,

WILLIAM TRELEASE,
Director.

SCIENTIFIC PAPERS.

STUDIES ON THE LIGNIN AND CELLULOSE OF WOOD.*

BY PERLEY SPAULDING.

INTRODUCTION.

In a recent paper Potter † gives the results of some investigations upon the cellulose and lignin of the xylem of tree stems. By microchemical methods he found that cellulose occurs as a distinct lining layer in the walls of the wood fibers of perfectly healthy trees grown in various parts of England. Trees of *Quercus*, *Fagus*, *Aesculus*, *Salix*, *Ulmus*, *Alnus*, *Betula*, and *Fraxinus* were found by him to have cellulose occurring in this manner through all parts of the stem; that is, in both heart and sap wood at varying distances from the bark. He tested the action of boiling water upon the lignin of the cell walls of wood by cutting microscopic sections and placing them in water in a "boiling tube" and boiling for about two hours per day on consecutive days, the sections remaining in the water all of the intervening time. The lignin began to leave the walls in four to six hours of boiling in the sections of *Fraxinus* and similar results were obtained with other woods, twelve hours being the longest period of boiling which is definitely mentioned by him. Simple soaking of small fragments of wood in cold water was then tried and it was found that a substance was obtained which had

* A thesis presented to the Faculty of Washington University, in candidacy for the degree of Doctor of Philosophy, April, 1906. — Published by permission of the Secretary of Agriculture.

† Potter. Annals of Botany. **18**: 121–140. (1904).

been extracted from the wood and which gave lignin reactions with phloroglucin and thallin sulphate, thus indicating a partial delignification of the treated wood. He was led to conclude that, "It is found that a gelatinous thickening layer which reacts at once to the various color tests for cellulose occurs very commonly, though very irregularly, in the fiber walls of the xylem as a normal condition in a great number of perfectly healthy trees, in all localities and situations. It may have a very partial distribution, or may occur very generally and conspicuously through the stem, and may be present only in parts of the same annual ring. Sometimes this innermost layer is represented only by a thin lining, at others by a very broad band which appears swollen and occupies a large part of the lumen."

Also, "The presence of this unlignified layer in the wood fibers probably represents a stage of arrested development. Its general prevalence having been overlooked, the conclusion is inevitable that the occurence of cellulose which has been attributed to the action of fungi must to some extent be ascribed to conditions already present and the effect of any method of sterilization must also be taken into account. The delignification cannot be attributed to an enzyme secreted by fungi."

AIMS OF THE PRESENT INVESTIGATIONS.

This paper with its rather striking results and conclusions led to the investigations here detailed. Tests were made: first, to determine the prevalence of cellulose in the stems of the trees of America; second, to confirm or disprove the results of Potter's work in testing the effect of boiling water upon the lignin of wood; third, to test the relative solubility of the lignin of the spring and summer wood of the annual ring of growth; fourth, to come to some understanding of the conditions existing in wood

when used in testing the action of fungi upon its component parts.

MATERIALS USED.

The present experiments were performed with freshly cut wood taken from the stems of trees which, with but few exceptions, were above six inches in diameter. Two sets of experiments were carried on: the first, of a preliminary nature, included but a few species of wood; while in the second, woods of about forty of the more common and important timber trees were tested. Still later a number of other species were examined for the presence of cellulose without performing the boiling experiments.

The species of wood used in the preliminary experiments were:* *Populus tremuloidus* from New Mexico; *Pinus palustris* from Texas; *Sassafras Sassafras*, *Taxodium distichum* and *Nyssa aquatica* from Arkansas; *Acer Saccharum*, *Quercus rubra*, *Hicoria ovata* and *Picea rubens* from Vermont; *Fraxinus Americana* and *Liriodendron Tulipifera* from New York; and *Larix Americana* from Michigan.

Further and more thorough tests were made later with a much larger number of woods, including most of the important timber species of the country. As will be perceived, those species which were utilized in the first experiment were also included in the later tests. The woods used in these last experiments are: *Sassafras Sassafras*, *Taxodium distichum*, *Nyssa aquatica* and *Liquidambar Styraciflua* from Arkansas; *Sequoia sempervirens*, *Sequoia Wellingtonia*, *Pinus Lambertiana*, *Pinus ponderosa*, *Pinus flexilis* and *Pseudotsuga mucronata* from California; *Catalpa speciosa* from Kansas; *Tilia Americana*, *Populus balsamifera*, *Larix Americana*,

* In naming the trees Professor Sargent's recently published Manual of the Trees of North America is followed.

Abies balsamea, *Pinus Strobus*, *Thuja occidentalis*, *Fraxinus nigra* and *Fagus Americana* from Michigan; *Pinus Taeda* and *Quercus rubra* from Mississippi; *Acer saccharinum*, *Cercis Canadensis*, *Pinus echinata*, *Cornus florida*, *Carpinus Caroliniana* and *Platanus occidentalis* from Missouri; *Juglans cinerea*, *Juglans nigra*, *Quercus Prinus*, *Ulmus Americana*, *Pinus divaricata* and *Hicoria ovata* from New Jersey; *Tsuga Canadensis*, *Picea rubens* and *Liriodendron Tulipifera* from New York; *Tsuga heterophylla* from Oregon; *Juniperus Virginiana* and *Nyssa aquatica* from Tennessee; *Pinus palustris*, *Ilex opaca*, *Magnolia glauca* and *Quercus Phellos* from Texas; *Acer Pennsylvanicum*, *Acer rubrum*, *Prunus serotina*, *Betula lutea*, *Acer Saccharum*, *Ostrya Virginiana* and *Salix* sp. from Vermont; and *Libocedrus decurrens* from Washington.

Attention should be given to the fact that much of the material used by Potter in his work was taken from branches and not from the main stems of the trees. Whether there is any difference between the branches and the stem with respect to the amount of unlignified cellulose present is as yet not definitely known; but the possbility of such a difference should be kept in mind.

CELLULOSE TESTS.

The examination for cellulose was at first performed simply with the microscopic sections after they were cut ready for use, but it was soon perceived that this method would not give accurate results. The samples of wood were then very carefully examined in all parts. If no cellulose was then found another search was made to make sure that it had not been overlooked at first. Thus the specimens which had no cellulose were really subjected to a much more rigid examination than were those which proved to have it.

Cellulose is said to occur in two ways in the fibers of wood in tree stems:* much more commonly as an inner, lining layer sometimes completely filling the cell lumen; and much more rarely as a layer situated between other lignified ones. Personal examinations have shown it to occur, with few exceptions, as an inner, supernumerary layer, but it has also been found that in exceptional cases nearly the whole secondary layer of the wall, which is usually completely lignified, gives a cellulose reaction although the reaction is more marked as we pass from the middle lamella to the cell lumen.

In the first lot of samples used for the preliminary tests it was found that cellulose occurred only in the wood of *Populus tremuloides* from New Mexico and in the wood of several trees of *Larix Americana* from the same locality in Michigan. In both cases the cellulose occurred only in some of the wood fibers and was present in the form of a lining, supernumerary layer of the wall.

In the more extended examinations made later cellulose was found in the wood of *Populus balsamifera* from the same locality as were the above mentioned trees of *Larix Americana* from Michigan. It may be added that a tree of *Populus tremuloides* from Vermont also showed large quantities of cellulose in the wood fibers. The occurrence of cellulose so markedly in all of the specimens of *Populus* wood available led to the suspicion that the species of the genus *Populus* might be characterized by this phenomenon wherever they might grow. Accordingly an effort has been made to obtain, as far as possible, specimens of all of the native species of this country. Of the eleven species which are listed by Sargent† in his latest publication the following have been examined: *Populus tremuloides*, *Populus balsamifera*, *Populus deltoidea*, *Populus trichocarpa* and *Populus acuminata*. Every specimen

* Sanio. Bot. Zeitung. **1863**: 101–111. † Sargent. *l. c.*

examined has had cellulose very abundantly and in thick layers such as are shown to occur in the wood of *Populus tremuloides* in plate 1 figure 1, and of *Populus balsamifera* in plate 2, figure 2. Consequently there seem to be good indications that the genus *Populus* is characterized by the occurrence of cellulose in an extra layer.

A number of species of *Salix* from widely scattered localities have also been examined. *Salix alba* was found to have an inner lining layer of cellulose in some of the fibers of the wood. *Salix fragilis* had a very pronounced layer in stems about four years old. *Salix* sp. from California had cellulose in nearly all of the wood fibers. *Salix fluviatilis* from South Dakota had a very pronounced cellulose lining in many of the fibers. *Salix viminalis* has been found to have a thin layer of cellulose in the fibers.

Beside the above species of *Populus* and *Salix* which have been personally found to have unlignified cellulose there are a number of cases which other workers have noted. Sanio * found it to occur in wood of *Populus pyramidalis*. Sablon † found it in wood of *Salix* sp.

The sections of *Populus* and *Salix* were found to have the cellulose in the form of a thick and very distinct inner layer of the fiber wall which seemed to be somewhat loosely attached to the secondary lignified one. In some cases it filled the entire cell cavity, but this was not commonly true. The cellulose layer was quite sharply delimited from the lignified one. Cellulose was never present in the cells of the oldest wood of the annual rings, but was always situated in the more open early wood. It was found only in the wood fibers and only in those fibers which do not join or abut upon the vessels and tracheids.

In the *Larix* sections cellulose was present only in certain of the annual rings and also only in the wood fibers.

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* Sanio. *l. c.* † Sablon. Rev. gén. d. Bot. **16**: 360–363. (1904).

It consisted of an inner, lining, layer which was not as thick as was that of the *Populus* species.

Later and more protracted examination of the other woods showed cellulose to be present in small quantities in a single ring of the wood of *Acer Pennsylvanicum*. It was also noted in wood of *Acer saccharinum*, *Catalpa speciosa*, *Nyssa aquatica*, *Pinus Taeda*, *Platanus occidentalis* and *Ulmus Americana*. It was present in all of these only in small quantities.

BOILING TESTS.

The boiling tests were performed as follows: transverse and longitudinal sections of the wood were cut, placed in distilled water in sterile test-tubes, and boiled in an Arnold sterilizer for two or three hours per day in a manner similar to that commonly used in the discontinuous sterilization of culture media. Attention is here drawn to the fact that the temperature reached in the Arnold sterilizer is about 100 degrees Centigrade. The boiling was continued until a total of twenty hours had been attained. The tubes were then placed in an autoclave and steamed at a pressure of about sixteen pounds and a temperature of about 120 degrees Centigrade. This steaming in the autoclave was continued until forty hours of boiling had been accomplished.

After fifteen hours of boiling in the Arnold sterilizer a faint appearance of delignification was perceived in the sections of *Sassafras Sassafras*. Twenty hours of boiling made it very pronounced. See plate 2, figures 3 and 4. After seven hours in the autoclave, or a total of twenty-seven hours of boiling, the sections of *Picea rubens* also showed a light blue reaction in the inner lignified layer of the fiber walls when treated with chlor-iodide of zinc. See plate 2, figure 1. With these two exceptions the forty hours of boiling seemed to have no effect upon the

lignin of the sections. Potter does not state at what temperature his experiments were carried on but it is presumably at about 100 degrees Centigrade. If his results were applicable to woods in general the delignification in the present experiment should have been apparent even sooner than it actually was; and it should have taken place in all or nearly all of the woods instead of but two out of the twelve which were used. But we find none of the woods were delignified in the time stated by him to be effective with the woods tested by him. Apparently then the woods used in these experiments are more thoroughly lignified or else hold their lignin in combination more firmly than was the case with the woods used by Potter.

The later boiling tests were performed wholly with the autoclave at a temperature of about 120 degrees Centigrade. In general it may be said that many of the woods gave evidence of delignification after fifteen hours of treatment, and nearly all, after eighteen hours of steaming. *Sequoia Wellingtonia*, *Betula lutea* and *Juglans nigra* gave no results so far as could be detected, but it is barely possible that these woods are dark colored enough so that the reaction was not seen even if obtained.

SOLUBILITY OF LIGNIN IN SPRING AND SUMMER WOOD.

An experiment was next tried to test the relative solubility of the lignin of the early and late wood of the annual rings. For this purpose a wood was chosen which showed a decided difference between the two parts of the ring. *Pinus palustris* seemed to be very good, having a decided difference in the thickness of the fiber walls of the spring and summer wood, and also being entirely free of unlignified cellulose. Microscopic sections were cut from fresh wood and boiled in the manner above indicated. After a very long period of boiling, a record of which was unfortunately not kept, it was found that the spring wood seemed to be

wholly delignified, but the summer wood was still lignified, and so far as could be noted showed very little effect from the boiling. The various cellulose and lignin tests were used and invariably indicated the same results. See plate 1, figure 2. Thus it seems to be proved that the lignin of the spring wood is held in combination less firmly than is that of the summer wood. This is probably due to the greater thickness of the walls in the summer wood, as the difference in thickness between the two parts of the ring was very marked as will be readily perceived on referring to plate 1, figure 2. The results of this test seem to furnish a clue as to the reason why certain of the wood rotting fungi disintegrate the walls of the spring wood while the summer wood of the same ring is apparently unaffected.

Later tests with the various woods enumerated above have shown that what is true of the wood of *Pinus palustris* is also true of many others. The degree of differentiation between the two parts of the annual ring seems to be the controlling factor in the relative solubility of the lignin of those parts. In other words, those woods which have a decided difference between the spring and summer wood of the annual ring are almost sure to have the lignin extracted from the former quicker than it is from the latter: and those woods which have but slight differences between the two parts of the ring are apt to have the lignin extracted from all or nearly all of the ring at the same time.

ENVIRONMENT AND LIGNIFICATION.

Potter's results may be accepted as true for the woods used by him but they cannot be taken as significant with respect to woods grown under all conditions. The above experiments have shown that there is a decided difference between the results obtained by him and those of the present tests. As is well known, there is a very great difference in the environment of trees grown under different

conditions and in different climates. All workers with wood recognize the fact that its strength is a very variable quantity and for that reason it is unsatisfactory for use in heavy structures, since the amount of stress which it can withstand is more variable than is that of steel and iron. There is a decided difference between a certain species grown on dry hills and the same species grown in moist lowlands. Much more then must there be a difference between wood of the same species when grown in essentially different climates. May not, in the same way, the degree of lignification of the walls be affected by external conditions? Potter * says, "local conditions of soil and climate seem in some cases, to retard the complete development of the xylem, and thus render such trees constitutionally weak and very liable to attack." Von Schrenk † has also intimated something of a similar nature in connection with *Fraxinus Americana* when growing on the western border of its range. He says, "In the present instance it would seem that there might be some relation between the greater susceptibility on the part of the ash near its western limit and its generally weaker development at this limit. It will be an interesting point to determine for instance whether the rate with which branch wounds or stubs heal in Ohio and Pennsylvania is greater than in Missouri and Kansas. That the rate of growth is slower in the Western States we know." In the same way may not the firmness with which the lignin is held in combination with the other constituents of the wall be also affected by the external conditions? This certainly does vary as is shown by the preceding experiment upon the spring and summer wood.

ARRESTED DEVELOPMENT AND RESERVE STORAGE.

The occurrence of cellulose in the form of an inner,

* Potter. *l. c.*

† Von Schrenk. U. S. Dept. Agric. Bureau of Plant Industry. Bull. 32: 11. (1903).

ACC NO: - 5534

supernumerary, lining layer of the fiber walls has been held by several botanists to be due to arrested development of the walls. It has seemed to the writer that there are certain facts in connection with cellulose thus situated which point directly against this theory. First, cellulose as above mentioned forms an *extra* layer of the wall. In other words the wall is completely formed and has, besides the usual layers, an extra one consisting of cellulose. Measurements of the fiber walls of *Populus balsamifera* show a difference of five microns in favor of the walls having the cellulose layer, over those which do not have that layer. Second, the wall with the cellulose layer is thicker than that without the cellulose, as is shown by the above measurements. It may also be stated that the difference in most of the woods was striking enough so that the observer could easily perceive without measuring that there was a decided difference between the two kinds of walls. Third, those fibers which are situated near vessels or tracheids do not usually have the cellulose layer. That is, those fibers which commonly do not have starch deposited within them are the ones which seem to be more apt to have the cellulose. This might be connected with the conversion of the starch into cellulose in such of the fibers as do not have the starch. Sablon* has proved that in willow wood the cellulose is plentiful when the starch has disappeared almost completely, and there thus seems to be a direct conversion of the starch into the cellulose. Fourth, the tendency is for the cellulose to be present in the spring wood and not in the summer wood of the annual ring where it would seem that arrested development would be most apt to affect the formation of the wall. There has been noted no indication of the final lignification of this cellulose layer, although Sanio† has stated that he noted such

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* Sablon. Revue générale de Botanique. **16**: 362. (1904).

† Sanio. *l. c.*

indications in certain stems which were especially favorable for the purpose. There certainly is still much doubt whether all the stems having this cellulose layer do finally become wholly lignified, and this seems especially true of the Salicaceae.

The exceptional cases mentioned above where the cellulose seemed to extend into the secondary layer (which is usually lignified), are not considered in this connection. Indeed they may very well be due to arrested development and are here so considered.

DELIGNIFICATION BY FUNGI.

Potter states that "the conclusion is inevitable that the occurrence of cellulose which has been attributed to the action of the fungi must to some extent be ascribed to conditions already present," implying that the cellulose which is found as a supernumerary lining layer of the wood fibers is the same cellulose which is found in woody tissues which are badly rotted by certain of the wood rotting fungi. He very evidently had in mind certain experiments of Ward * and Biffen † in testing the action of *Stereum hirsutum* and *Bulgaria polymorpha* upon wood when grown in pure cultures upon it. In both of these cases it happens that the delignification was apparently not very extensive and affected but a portion of the wall. In making the above statement Potter was at least partly correct in applying it to such cases, where the delignification was rather slight and affected but a portion of the wall. The statement should have been limited to such cases, as it is not applicable to those where the delignification has taken place throughout the whole wall as is the case in the last stages of disease caused by many of the wood rotting fungi, for the cellulose of normal wood occurs in such a

* Ward. Phil. Trans. Royal Soc. **189.** Series B. (1897).

† Biffen. Annals of Botany. **15**: 119–133. (1901.)

manner that it can have little or no effect upon the final result where the delignification is extensive, as is shown quite conclusively a little later in this paper.

The cellulose which is so often found in wood undergoing the last stages of decay is the cellulose skeleton or framework of the secondary, lignified layer which is universally present in old wood fiber walls, whether they have the supernumerary cellulose layer or not. That this is so is proved by a careful examination of the various stages of rot caused by any one of the numerous wood rotting fungi which delignify woody cell walls. The published work and drawings of Robert Hartig * alone are sufficient to prove this, as it has been found by the writer that cultures from rotted wood in the middle of a decayed stem of a living tree, if the exterior layers of wood are still alive, invariably yield but a single fungus, thus proving that the attacking fungus occurs in a pure state at least in most cases. If there is any cellulose layer present in the wood before it is attacked it is probably the first part of the cell wall to be dissolved and it is fairly certain that it does not exist in the last stages of decay.

Two instances of trees attacked by wood rotting fungi which fully bear out the last statement have recently come to the writer's attention.

A tree of *Carpinus Caroliniana* was found badly decayed by *Polyporus gilvus*,† which in this case seemed to be a wound parasite. At the edge of the affected wood was a narrow border of dark, infiltrated cells separating the healthy from the diseased wood. In the healthy wood just outside this infiltrated zone the wood fibers in many cases had an inner, lining layer of cellulose. This layer disappeared in the infiltrated zone while in the very badly

* Hartig. Wichtige Krankheiten der Waldbäume. 1–127. (1874); Die Zersetzungserscheinungen des Holzes der Nadelholzbäume und der Eiche. 1–151. (1878).

† Engler & Prantl's Pflanzenfamilien is followed in naming the fungi.

rotted tissues the cell walls consisted only of cellulose, the lignin appearing in greater and greater quantity as the healthy wood was approached. This single instance alone seems to prove that the cellulose layer of the healthy wood does not have any connection with the cellulose left by the action of the fungus upon the cell wall.

Still another instance was noted which seemed to confirm and make this point doubly certain. Sections of trunks of trees of *Populus tremuloides* rotted by *Fomes igniarius* were examined carefully for the occurrence of cellulose. It was found that the wood fibers of the healthy wood in most cases had an inner, supernumerary layer which turned blue with chlor-iodide of zinc. The rotted tissues were separated from the healthy ones by a narrow infiltrated zone. Just inside this zone of infiltrated cells the affected fibers were of a very uniform thickness and the walls were decidedly thinner than those of the healthy wood where the cellulose was present. In the rotted tissues the cell cavities were also larger than in the unaffected cells. In other words the cellulose layer is more or less completely dissolved from the interior of the fibers, and the secondary layer is delignified, while the cellulose skeleton is left until the last.

These two instances seem to show that there can be no doubt regarding the solution of the supernumerary cellulose layer during the early stages of decay caused by some of the fungi. It is believed that this will prove to be true of most if not all of them. Hartig very evidently understood this and for this reason gave no further attention to the occurrence of cellulose as an extra layer in the wood fibers of oak wood than to mention its occurrence.*

Actual measurements made in the wood fibers of the healthy and rotted wood of the same sections show beyond

* Hartig. Die Zersetzungserscheinungen des Holzes der Nadelholzbäume und der Eiche. 94. (1878).

any doubt that the thickness of the healthy wall is greater by a decided difference than is that of the cellulose fiber walls which are left in the badly rotted tissues. Such measurements have shown a difference of about a third of the total thickness of the original healthy wall between the two series. It has been stated distinctly by practically all workers with this group of fungi that delignification is a very common phenomenon as a result of the action of the mycelium of these fungi, which grows in the wood and disintegrates it to a greater or less extent as the case may be.

That cellulose is left by many of the fungi in the last stages of decay of the wood in which they are growing is but a very natural phenomenon to one who is familiar with the structure of woody cell walls. Chemical analyses have shown that cellulose is the basis of the structure of the wall and makes up a large percentage of it by dry weight. The methods of analysis are, to be sure, not satisfactory for exact quantitative results since each method gives results varying from the others by a small margin, yet the figures obtained may be used provided we keep in mind the fact that they are but approximate. Czapek * has given a summary of what has been done in this connection by different chemists. The following table shows the results obtained by two of the best methods of analysis.

	LANGE.	SCHULZE.
Beech	54.0-53.0-53.0	51.0-50.5-50.0
Fir.	51.0-50.0-50.6	48.0-48.2-49.0
Oak.	55.0-56.0-56.0	52.0-52.0-52.5

The figures indicate the percentage of cellulose found in the woods named by the two methods of analysis and also show the amount of variation in the results obtained. Analyses of pine wood showed that the percentage of cellulose varied from 47.5 to 53.5 per cent, and it was found that the sap wood was richer in cellulose than was the

* Czapek. Biochemie der Pflanzen. 1 : 563-564. (1905.)

heart wood. In general it may be said that from 45 to 60 per cent of wood is cellulose. Besides all this, pure cultures of several of the more common of the wood rotting fungi have been grown upon blocks of wood, which so far as could be determined, had no unlignified cellulose in the cell walls, and delignification has resulted while similar control blocks have shown no such delignification.

EFFECT OF STERILIZATION UPON WOOD BLOCKS.

When it is considered for how long a time the thin microscopic sections of the various woods were submitted to boiling at extreme temperatures before any decided effect could be detected one can hardly say that the effect of boiling at 100 degrees Centigrade for the time necessary for sterilization can be appreciable in cell walls in the interior of relatively large blocks of wood such as are commonly utilized for cultures of the wood rotting fungi. It seems that the effect upon the lignin of a block of wood which the investigator is sure has no unlignified cellulose originally, is so slight that it may be neglected. This is still more true when we remember that simple soaking has a more or less solvent effect upon the lignin in any method of culture work. There can be no doubt that when finely divided wood is soaked in water or is boiled, lignin is extracted in sufficient quantity for lignin reactions to be obtained in the filtrate from the extracted material. But this is very different from the detection of that extraction by micro-chemical examination of the treated walls themselves; for it must be confessed that micro-chemistry furnishes methods which are far from accurate for quantitative analysis.

In testing the action of fungi upon wood we must keep in mind the solvent action of boiling and of continual soaking in water and not be too hasty in drawing conclusions from meager results which might be confused with such action of boiling or soaking. Control tubes of wet wood

and careful examination of the material used should obviate much of this difficulty however.

ENZYMES OF FUNGI.

Potter also states that, "the delignification cannot be entirely attributed to an enzyme secreted by fungi." As above stated it has been shown that the original thickness of wood fiber walls is very materially reduced by some agent at the very time when the fungus is attacking the tissues in question. It is also shown that the cellulose which may or may not be present in the walls *before* they are attacked certainly is not the same unlignified cellulose which is present *after* the destruction of the wood by the fungus. It seems certain then that fungi do delignify woody cell walls.

There can be no doubt that enzymes, or some substance exhibiting the characteristics of enzymes, have been proved to exist in some of the fungi and indeed in some of the wood rotting ones. Such investigations as have already been published in this connection would seem to prove beyond any reasonable doubt that enzymes are secreted by fungi and that they are of the most varied character. Diastase seems to be proved to be present in many of the different fungi and in the wood rotting ones. The disappearance of starch in the early stages of attack of some of the wood rotting fungi upon wood seems to be generally attributed to the secretion of diastase by the fungi. Why should the disappearance of lignin from the fiber walls, leaving cellulose in the last stages of decay, be attributed to any other cause than the secretion of a delignifying enzyme until we have proof of some other agent which is capable of such action? To be sure, the separation of an enzyme or a juice showing enzymic action from the fungus being studied is the exact proof of the existence of an enzyme; yet when we consider that enzymes are accepted

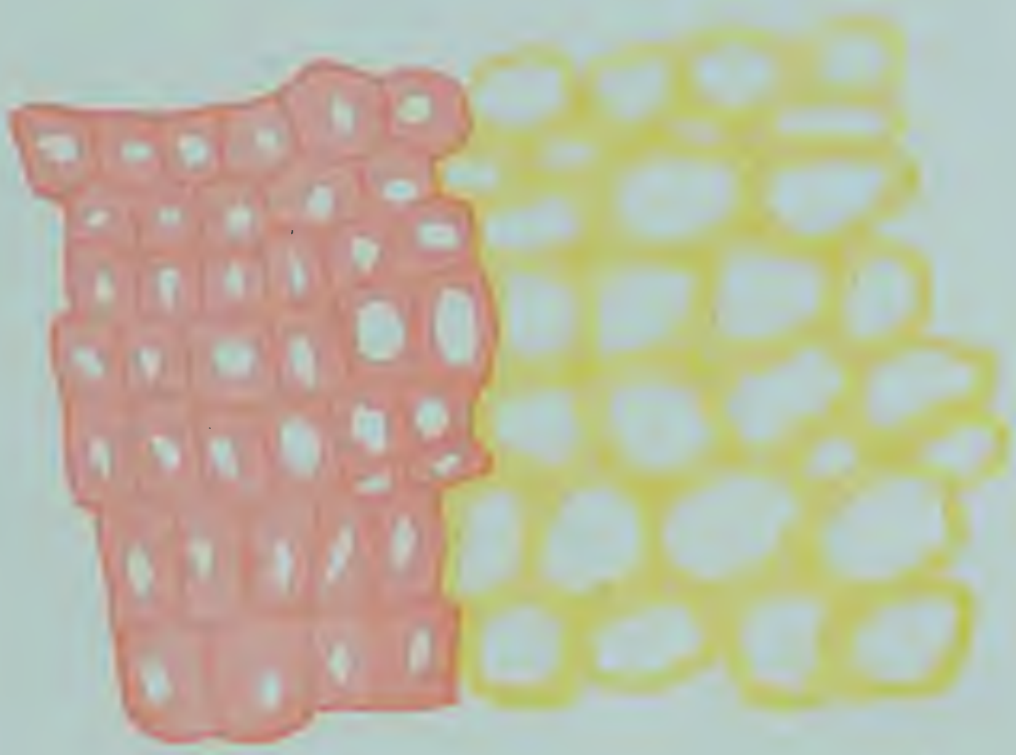
by practically all botanists as being present in fungi we can hardly come to but one conclusion regarding the existence of a delignifying enzyme.

EXPLANATION OF PLATES.

Plate 1. — 1, Portion of transverse section of wood of *Populus tremuloides* showing several wood fibers with a third, inner, cellulose layer. This layer is colorless, as the section is stained with phloroglucin which is a test for lignin. This supernumerary layer is characteristic of the species of the genus *Populus* so far as they have yet been examined, five of the endemic North American species from the various parts of the country having been tested. 2, Portion of a transverse section of wood of *Pinus palustris* showing one annual ring of growth. The thicker walled cells form the summer wood of the ring, while the thin walled ones make up the spring wood. This section has been boiled until the lignin was extracted from the spring wood, and was then stained with phloroglucin, a test for lignin. The red walls have reacted with the chemical showing that lignin is still present in the summer fibers. The yellow cells have retained their normal color to a greater or less extent and gave no reaction with the phloroglucin, thus showing that they have been delignified quite completely. The section shows the relative solubility of the lignin in the two parts of the annual ring.

Plate 2.— 1, Portion of a transverse section of wood of *Picea rubens* boiled for 27 hours. This has been stained with chlor-iodide of zinc, a test for cellulose. The cellulose has been colored blue while the other parts of the walls are of their normal color. This shows the delignifying action of boiling water upon the lignin of the fibers. 2, Transverse section of wood of *Populus balsamifera* cut from a freshly felled tree and stained with chlor-iodide of zinc. The thick supernumerary layer of cellulose is colored blue. 3, Transverse section of wood of *Sassafras Sassafras* boiled 20 hours and stained with chlor-iodide of zinc. This is drawn with a smaller magnification than are the other figures. It shows the frequency of the cellulose layer, in the fibers of the wood. Note that there is no cellulose present in the last cells formed in the ring, which are in a vertical line near the left of the figure. 4, Transverse section of wood of *Sassafras Sassafras* drawn on the same scale as the other figures. This was boiled and treated with chlor-iodide of zinc and shows the character of the delignified layer in the fibers. Most of the fibers adjacent to the vessels and tracheids do not have the cellulose layer.

1



2

LIGNIN AND CELLULOSE.

LIGNIN AND CELLULOSE

STUDIES UPON SOME CHROMOGENIC FUNGI WHICH DISCOLOR WOOD.*

BY GEORGE GRANT HEDGCOCK.

GENERAL REMARKS.

The discoloration of unpainted woodwork exposed to moisture and to oxidation by the air is a familiar phenomenon. Of course much of this discoloration is due to the dirt and soot which accumulate on the surface of boards in addition to the chemical changes which take place through weathering. There is also a class of stains of an entirely different nature and more striking to the eye. These occur on freshly sawn lumber in piles. It was in the investigation of the most important of these lumber stains in the study of the western yellow pine, *Pinus ponderosa*,† under Dr. Hermann von Schrenk of the Mississippi Valley Laboratory, of the United States Department of Agriculture, that the studies upon which this paper is based were begun. In addition to the blue stain in pine lumber, brown, black, pink, purple and yellow stains and blotches were noted, not only on pine boards, but also on gum, poplar and other kinds. These were found to be caused by a number of fungi, some of which were quite different from that which causes the blue stain of the western yellow pine, viz: *Ceratostomella pilifera* (Fr.) Winter. Again the bluing of wood was found to be the result of the action of more than one species of *Ceratostomella*.

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* A thesis presented to the Faculty of Washington University, in candidacy for the degree of Doctor of Philosophy, April, 1906. Published by permission of the Secretary of Agriculture. — Type cultures of all of the species described as new in this paper have been divided into parts deposited respectively in the United States National Herbarium, the Physiological and Pathological Herbarium of the United States Department of Agriculture, and the Missouri Botanical Garden Herbarium.

† Von Schrenk, H. Bull. Pl. Ind. 36: 1–27. (1903).

The work of investigation has been undertaken primarily on account of the value of the knowledge which might accrue through the study of the chromogenic fungi or bacteria which are concerned in the color reactions which take place in stained lumber; yet, on the other hand, the economic value of the work has not been lost sight of, owing to the loss of hundreds of thousands of dollars to the lumber industry each year due to the lowering of the grade of lumber in piles through the rapid action of many tiny wood staining fungi.

In the study of the fungus flora of the lumber pile a large number of forms have been observed not all of which discolor the substratum upon which they grow. Attention has been given not only to those which penetrate wood deeply and stain it, but also to those which discolor it only superficially.

In the isolation and culture of the fungi herein described, recourse was had to the most careful bacteriological methods, such as are described by Dr. Erwin F. Smith * in his excellent monograph on "Bacteria in relation to plant diseases." In a number of instances new conidial stages of fungi have been discovered, and in every instance the relation of the new form to the older known forms has been repeatedly established by starting with the newly discovered stage and following the fungus through all its known stages and back again to the beginning. The saprophytic nature of the forms studied made it possible to start with single colonies on a poured plate of agar medium and make transfer cultures to test tubes of sterile wood or other media. Each fungus was grown upon a number of kinds of wood, as well as upon potato, rice, bean, sweet potato, and other similar media in tubes, in addition to cultures upon agar media made from wood and other vegetable decoctions.

In order to better establish varietal and specific charac-

* Smith, E. F. Bacteria in relation to plant diseases. 1. (1905).

ters, parallel cultures of related fungi have been grown on sets of the same media in conditions as nearly identical as can obtain in an ordinarily well-equipped bacteriological laboratory. In order to make drawings of the delicate conidial stages of some species it was often found necessary to grow the colonies in Petri dishes of thin glass, and study them in the open in the dish, without placing a cover glass over the very fragile hyphae.

It is thought best to arrange the results under the following groups or heads: —

WOOD-STAINING FUNGI.

I. Wood-bluing fungi.
   1. *Ceratostomella.*

II. Wood-blackening and wood-browning fungi.
   1. *Graphium.*
   2. *Hormodendron.*
   3. *Hormiscium.*
   4. Other wood-blackening fungi.

III. Wood-reddening fungi.
   1. *Penicillium.*
   2. *Fusarium.*

In conclusion of these introductory remarks, grateful mention should be made of the valuable assistance to the work of investigation accruing through the use of the library and other facilities of the Missouri Botanical Garden, kindly tendered by Dr. William Trelease, the Director. Acknowledgment also should be made of the helpful co-operation of Dr. Hermann von Schrenk, Mr. Perley Spaulding and Miss Laura L. Eames, of the Mississippi Valley Laboratory, and to Dr. A. D. Hopkins, of the Bureau of Entomology of the United States Department of Agriculture, for securing material for study and granting other similar favors.

I. WOOD-BLUING FUNGI.

The blue stain in pine wood has been known in Europe for

many years. Hartig * and Frank † both refer to it in their publications on plant diseases. Hartig ascribes the cause of bluing to *Ceratostoma piliferum* (Fr.) Fuckel, which is now placed under the genus *Ceratostomella* according to Winter. This species was first described by Fries, who placed it under the genus *Sphaeria*, where it remained with other species until Fuckel placed it under the genus *Ceratostoma*. Winter,‡ in the revision of the genus *Ceratostoma*, placed all species with colorless ascospores under the new genus *Ceratostomella*.

Von Schrenk § in a bulletin of the Bureau of Plant Industry, U. S. Department of Agriculture, fully describes both the fungus *Ceratostomella pilifera* and its effect and mode of entrance into the wood of *Pinus ponderosa*.

A large number of species of *Ceratostomella* are described by Saccardo,¶ many of which occur on wood, but no reference is made to the staining effect of any of these species. There is little doubt that a number of these are wood-staining fungi, but from the results of our investigations it appears that the common bluing fungus is *C. pilifera*.

1. Ceratostomella.

Winter in Michelia characterizes the genus *Ceratostomella* as follows: "Perithecia superficial or partly immersed, usually tough, leathery or carbonaceous, glabrous or invested with filaments, with prominent well developed beak; asci without paraphyses, 8-spored; ascospores continuous, globose, ovoid or oblong, hyaline; spermogonia and conidia present in some instances."

Although Winter mentions that conidia are present in a few instances, a careful search through the literature on the subject reveals that the number of species which have

* Hartig, R. Lehrbuch der Pflanzenkrankheiten. 75, 106. (1900).
† Frank, A. B. Krankheiten der Pflanzen. **1**: 107. (1895).
‡ Saccarado, P. A. Michelia. **1**: 370. § *l. c.*
¶ Saccardo, P. A. Sylloge Fungorum. **1-17.**

conidia in their descriptions is very limited indeed, only two being noted, and where such descriptions have been given, no mention is made of the connection between the conidial and the perfect or perithecial stages as being established by cultural methods. For instance, *Ceratostomella albocoronata* (Ellis) Sacc. has a conidial stage where the conidia are from 2- to 3-septate, and of abnormally large size. So far as our investigation has proceeded, all species of *Ceratostomella* have colorless conidia, that are one-celled and of about the same measurements as the ascospores. The presence of asci in the perithecia has been the most difficult point to prove. Cultures must be taken at the stage just preceding full maturity of the ascus, else it apparently dissolves and frees the ascospores at maturity, allowing their free ejection through the long, narrow beak of the perithecium, but destroying the evidence of the presence of a sac. In an examination of the ejected ascospores they are frequently found adhering to each other in fours, side by side, in the same position they occupied in the ascus.

The conidial stage of *Ceratostomella* is very important, owing to the immense number of conidia borne on the mycelium in its earlier growth. These are readily disseminated by the wind and are probably carried by insects which penetrate the wood and bark of trees, like most of the ambrosia and bark beetles. At the stage in which the conidia form a mucilaginous mass, they adhere readily to any insect that may pass over them. In the laboratory a number of species of mites which feed on fungi carried spores on their bodies from a colony in an agar plate to a sterile portion of the surface of the medium and started new colonies of the fungus. Bark beetles were placed in a dish with the conidial stage of *Ceratostomella*, and after allowing them to remain a short time were transferred to sterile agar plates which were inoculated with spores from the insects. It is probable that some species of in-

sects feed on the conidial stage of *Ceratostomella*, especially one or more species of ambrosia beetles and a number of mites infesting their channels in the wood; but proof is yet lacking on this point. The constant occurrence of this fungus in the channels of a number of wood boring beetles indicates that the conidia or the ascospores must be carried in some manner by these insects. Hopkins* describes some of these beetles in a bulletin of the U. S. Department of Agriculture, and von Schrenk† describes how *C. pilifera* follows the channels of wood-boring beetles in *Pinus ponderosa*. The writer has made similar observations on *Ceratosmella* in its penetration of *Pinus ponderosa*, *P. Arizonica*, *P. echinata* and *P. Virginiana*.

Although the genus *Ceratostoma* is very closely related to *Ceratostomella* none of the species of *Ceratostoma* have been found in connection with the blue stain of wood. In the course of the present investigation stained wood has been collected from a large number of localities, including wood from trees and shrubs of the following genera: *Abies*, *Acer*, *Fagus*, *Fraxinus*, *Liquidambar*, *Liriodendron*, *Pinus*, *Rubus*, *Ulmus*, *Vitis* and *Wistaria*. A number of species and varieties of *Ceratostomella* have been identified, cultivated and proved to be wood-bluing fungi. *Ceratostomella pilifera* has been found far more prevalent than other species. As the conidial stage of this species was first discovered by the writer and the description has never been published, it will now be given. It is taken from the results obtained from a very large number of pure cultures grown and studied over a period of nearly four years.

Ceratostomella pilifera (Fr.) Wint.

This fungus has been isolated in cultures taken from stained wood from a number of species of *Pinus* taken from nearly every region of the United States. It pene-

* Hopkins, A. D. Bull. Div. Ent. U. S. Dept. Agr. 32: 9, 10.

† Von Schrenk, H. *l. c.*

trates rapidly the sap wood of dead and dying trees, giving it a peculiar blue tint whose color is hard to explain, since the mycelium of the fungus in the cells of the wood is a dark brown. It has also been found in the sapwood of species of *Abies*, *Quercus*, *Fraxinus*, and other genera.

Ceratostomella pilifera grows readily upon a large number of culture media. Pine decoction agar made from the bark and sapwood was found an excellent medium for its cultivation. Two distinct fruiting forms were observed in all the varieties, the conidial and the perfect or perithecial.

Mycelium.

When either the conidia or ascospores are sown in pine agar plates, germination takes place in a few hours, and in two days colonies with a white hyaline mycelium develop. The filaments are septate, and, as a rule, branch alternately. In a day or so upright hyphae, either simple or branched, are sent out, upon which are borne branching whorls of conidia. In the course of a week or so, portions of the mycelium in the older region of the colonies develop with thicker walls and assume a brown color. From these dark colored filaments the perithecia originate.

The first growth of the mycelium is usually sparse, but under favorable conditions a secondary profuse growth with a fluffy white appearance develops, which bears conidia, and the formation of perithecia is retarded. Such a growth is formed on some of the richer media made from pine and other plant decoctions. Under these conditions the development of conidia is enormous, and the number of perithecia is decreased somewhat. Cultures on the sapwood of trees in test tubes bear both stages of the fungus abundantly. On the heartwood, however, but few conidia are formed, the mycelium is almost invisible to the eye, and perithecia are either sparse or entirely absent. The filaments of the fungus never penetrate deeply into

the tissues of heartwood of pine, oak, ash, or similar woods in artificial cultures, which fact coincides with the observation that in nature, for some reason, the same thing happens, the older discolored heartwood being usually free from attacks by the mycelium.

Conidia.

The conidia are borne on erect or slanting hyphae which branch alternately from the mycelium. They develop terminally in branched or simple moniliform short chains which are often in whorls (pl. 4, f. 5). They are detached by the least movement, and in moist air fall together in agglutinated masses about the terminus of the hyphae, in a form which superficially resembles *Cephalosporium* (pl. 4, f. 6). These masses, however, are not so regular as the masses of conidia in the heads formed by *Cephalosporium*. The conidia bear some resemblance to those of *Ovularia*. The *Cephalosporium*-like clusters are always present in agar cultures after a few days' growth. The conidia vary from obovate to elliptical or cylindrical. They measure from 8μ to 12μ in length, and from 2μ to 4μ in width. They are hyaline when young, but often become vacuolate or guttulate when old. They are unicellular and borne on septate hyphae which are from 3μ to 5μ in diameter. Only hyaline filaments bear conidia. In germination the conidia send out terminal germ tubes from either end (pl. 4, f. 7).

Perithecia.

The first indication of the formation of perithecia on the mycelium is the union of two or more filaments and the formation of a knotted mass. The adjacent mycelium changes first to a light brown color, and later to a very dark brown. In the center of the mass the young perithecium develops first as a globular black body, without a beak or neck.

The walls of the perithecium are usually formed by one

layer of cells united in a rudimentary tissue. From the upper side of the young perithecium, after it has grown to about its normal size, there is projected a long tube or beak composed of parallel hyphae which terminate with colorless ends in a rounded tip. When the perithecium is mature it contains a large number of irregularly obovate or elliptical asci, each containing eight spores, usually arranged in fours. The beaked ostiolum, when the ascospores are ejected, splits at the end into a number of bristles which spread out and form a supporting crown for the ejected ascospores (pl. 3, f. 8). The perithecium without the neck measures 160μ in height and 180μ in diameter, average, and the neck about 1 mm. in height and 20μ in diameter, average. The ascospores average 5.5μ by 2.5μ.

It is quite evident that the sac containing the ascospores is dissolved at maturity, since it is rarely found with the mature ejected spores, but must be looked for in perithecia just approaching this stage. If the spores are ejected in open air they usually collect in a globular drop at the terminus of the neck, and when in this position the drop resembles very much the heads of some species of *Graphium* when covered with the mucus drop characteristic of the latter genus. If the spores are discharged in water they form worm-like sticky masses not readily miscible with water.

Ceratostomella Schrenkiana n. sp.

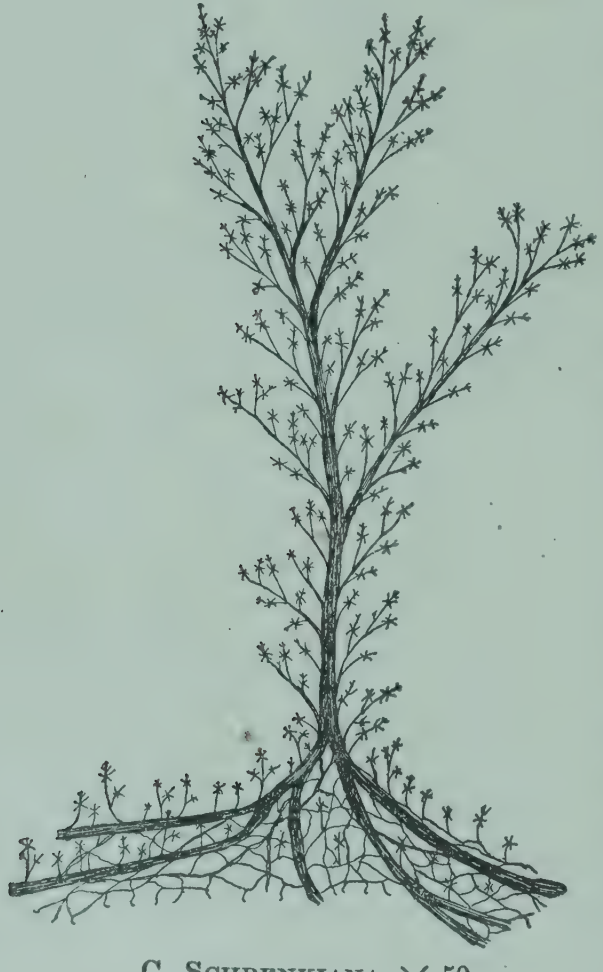
The sapwood of pine lumber made from *Pinus echinata* in Arkansas and other southern localities is stained by a number of fungi, among which are species of *Ceratostomella*, *Hormodendron*, *Graphium*, *Hormiscium* and *Penicillium*. A species of *Ceratostomella* which greatly resembles *C. pilifera* has been frequently collected on the wood of the southern pines by Dr. von Schrenk and others, from various localities in Missouri and Arkansas.

This species, when grown side by side with cultures of *C. pilifera* from the Black Hills pine, attains the same

size in so far as the colonies and perithecia are concerned; but on the other hand, both the conidia and ascospores are constantly much smaller. In nature, the perithecia that mature are often surrounded by several closely adhering dark bodies, which are either sclerotia or abortive perithecia, apparently the latter. This feature has never been noted with other species of *Ceratostomella*. In view of the differences, it is thought best to separate this form from *C. pilifera* and it is named *C. Schrenkiana*, in honor of Doctor von Schrenk, who first collected the fungus and noted its peculiarities.

The following cultural characters are taken from a large number of natural and artificial cultures: —

MYCELIUM.



C. SCHRENKIANA, × 50.
Dendroid fruiting tuft.

Conidia or ascospores, if sown on agar plate cultures, germinate in a few hours, and after a day have formed conidia, if the temperature is favorable. The most favorable temperature for growth is 80° to 90° F. The filaments and hyphae remain white for several days, and often become massed in a furry outgrowth in which strands of filaments unite into upright clusters or false heads. (See figure). After a few days' growth, portions of the mycelium lying next the agar become pigmented with a brown color, and rapidly develop

perithecia. The filaments of the mycelium measure 3μ to 7μ in diameter.

Conidia.

The conidia are borne in clusters similar to those of *C. pilifera* (pl. 4, f. 1, 2). They are unicellular, obovate to elliptical or cylindrical, and measure 3μ to 7μ by 1μ to 2μ, averaging 5μ by 1.8μ. They are hyaline and are usually neither guttulate nor granular, but when old may have one or two guttules.

Perithecia.

Perithecia are formed on the mycelium (pl. 4, f. 4), as in *C. pilifera*. The shape is spherical. They are coal black in color, and measure 120μ to 200μ in diameter, with a smooth, beaked ostiolum, measuring .8mm. to 1.2mm. in length by 10μ to 25μ in diameter, surmounted at maturity by a row of short, hyaline, spreading bristles, which support the ejected ascospores in a globular mass. The bristles measure about 10μ to 15μ by 2μ (pl. 3, f. 6). The ascospores are hyaline, pointed, elliptical, often slightly curved, and measure 2.5μ to 4μ by 1μ to 1.5μ, averaging 3.5μ by 1μ (pl. 4, f. 3).

This species resembles, in its gross measurements, the description of *C. echinella* E. & E. It differs, however, in that the perithecia are borne superficially, and are not glandular-pubescent or thickened at the tips. The mature perithecia are not gregarious, although they bear numerous small bodies at their base, under certain conditions.

Ceratostomella echinella E. & E.

The last species of *Ceratostomella* identified and studied before publication was collected by Dr. von Schrenk at Kirbyville, Texas, on the wood of the red beech, *Fagus atropunicea* (Marsh.) Sudworth. This was growing on freshly cut heart and sap-wood, staining the wood either a bluish or

a brownish color. The fungus was isolated and grown in pure cultures on the wood of the red gum and on pine decoction agar, as well as on tubes of rice, potato, etc., the following cultural characters being from both natural and artificial cultures. The description differs but slightly from that given by Ellis and Everhart* and has been emended by the addition of the conidial stage.

Mycelium.

The colonies resulting from either ascospores or conidia are white at first with a hyaline mycelium which later becomes pigmented in certain of the larger filaments, assuming a dark brown color. The filaments measure from 4 to 7μ in the mature forms. Conidia appear after 36 hours, and perithecia in four or five days.

Conidia.

The conidia are borne in short branching moniliform chains in small clusters, falling together in irregular masses as they mature (pl. 6, f. 1). They are unicellular, hyaline, becoming guttulate when old, obovate to elliptical, and measure from 4μ to 6.5μ by 2μ to 3.5μ, averaging 6μ by 3μ.

Perithecia.

The perithecia are brown at first, but when they are mature they become black and carbonaceous and are covered sparsely with short, glandular hairs. They are globose, or sometimes slightly flattened, measuring 50μ to 100μ in diameter. The hairs measure 10μ to 32μ in length by 1.5μ to 2μ. Each terminates in a gland or spherical enlargement measuring 2μ to 3μ in diameter. The perithecium is tipped by a long slender beak, black at the base, brown

* Ellis, J. B. and Everhart, B. M. North American Pyrenomycetes. p. 195. (1892).

or gray at the apex, but smooth throughout measuring 1 mm. to 1.7 mm. in length by 15μ to 25μ in diameter and surmounted when mature by a terminal fringe of bristles 15μ to 25μ in length and tapering from 4μ at the base to 1μ at the apex, being hyaline throughout (pl. 3, f. 3). The asci are clavate(?), bearing biseriate spores which are hyaline, curved or straight, elliptic to cylindrical, and which are ejected in the open air in a globular mass at the terminus of the beak.

Since writing the above, co-type material of *C. echinella* in the herbarium of the Missouri Botanical Garden has been examined. The perithecia are probably as described by Ellis and Everhart,* but they have persistent asci which contain brown two-celled ascospores, placing the fungus in the specimen under another genus. This indicates that at least a mistake was made in a portion of the material sent out as type specimens if not in the description.

Ceratostomella capillifera n. sp.

The wood of *Liquidambar Styraciflua* L. is an excellent pabulum for a large number of fungi, and lumber made from this tree, when in piles, soon becomes thoroughly stained either blue or black by the growth of a number of species of wood-discoloring fungi. Among these was found quite commonly a species of *Ceratostomella* which is closely related to *C. pilifera*, but differs in the length of the beaked ostiolum, the length of the terminal bristles and the shape and size of the conidia and ascospores. The following characters obtain with pure cultures: —

Mycelium.

Cultures of either conidia or ascospores sown on pine-decoction agar germinate quickly, forming a diffuse, white, hyaline, septate mycelium, which in less than two days

* Ellis, J. B. and Everhart, B. M. *l. c.*

bears hyaline conidia abundantly. In about a week, black, long-beaked pycnidia appear on certain portions of the mycelium, which assumes a brown color, the development being similar to that described for *C. pilifera*. The filaments of the hyaline portion of the mycelium measure from 2μ to 3μ in diameter, and the older brown-colored filaments, in wood, from 3μ to 6μ.

Conidia.

The conidia are borne like those of *C. pluriannulata*, and are similar in shape (pl. 6, f. 2, 3). They are unicellular, hyaline, elliptical to cylindrical, and measure 4μ to 8μ in length, and 1.5μ to 2μ in width averaging 6μ by 1.8μ.

Perithecia.

The perithecia are spherical, of a black color, with black, long-beaked ostiola, terminating in long, wavy hyaline filaments. The body of the perithecium is usually nearly covered with dark brown hyphae or filaments. It averages 200μ in diameter, and the neck 1.5 mm. in length and 25μ in width. The terminal filaments are long and slender and measure 80μ by 1μ, average (pl. 3, f. 1).

The ascospores are elliptical to reniform in shape and average 4.5μ by 1.5μ in size. It will be noted that although the perithecia of this species are larger than those of *C. pilifera* the conidia are somewhat smaller. Both ascospores and conidia usually germinate terminally, some few exceptions having been noted.

The name *C. capillifera* is given to this species on account of the long minute bristles which project from the ostiolum.

Ceratostomella pluriannulata n. sp.

A block of blued sapwood from *Quercus rubra* was collected in 1905 by Perley Spaulding and turned over to the

author for investigation. A species of *Ceratostomella* was found among the cells of the wood and fruiting quite abundantly on the surface. The characters of the fungus agree in part with *C. pilifera*, to which it is closely related. It has ascospores which are constantly of a slightly different shape, and is often characterized by more than one whorl of bristles on the beaked ostiolum. The conidia are considerably smaller, and the hyphae on which they are borne are more frequently branched, thus giving rise to larger clusters. Owing to the frequent presence of more than one ring of bristles on the ostiolum, the name *C. pluriannulata* is here given to the species, with the following cultural characters: —

Mycelium.

The growth of the mycelium from either conidia or ascospores resembles that of *C. pilifera*. The spores germinate in pine-decoction agar in 2 to 3 hours, and in 2 to 3 days a white, floccose mycelium bearing conidia appears. In from 5 to 10 days perithecia appear, the development of which is like that of *C. pilifera*.

Conidia.

The hyaline unicellular conidia are borne on branching septate, hyaline, upright hyphae in simple or compound whorls (pl. 5, f. 1). In the older portions of the colony, the conidia fall off and adhere in masses forming clusters resembling *Cephalosporium*. These clusters vary in size from 10μ to 100μ in diameter. The larger clusters are formed by the adherence of several spore clusters into one mass. The conidia measure 5μ to 8μ in length and 2μ to 3μ in width; averaging 6μ by 1.5μ.

Perithecia.

The perithecia are borne superficially on the wood, or on the mycelium, there being no definite stroma in this or in

the other species of *Ceratostomella* studied. The perithecia are globose, varying from 90μ to 200μ in diameter, and averaging 120μ. The lengthened beak measures from .9 to 2 mm. in length, and 10μ to 30μ in diameter, averaging 1.5 mm. by 25μ. Some of the necks, in addition to the ring of bristles ordinarily found at the terminus of the beaked ostiolum, have one or two whorls at some distance below the end (pl. 3, f. 7). This character has never been noted in cultures of *C. pilifera*. The terminal bristles are tapering and average 20μ in length by 2μ in width. The asci have not been measured. The ascospores are reniform in shape, hyaline, and measure 4μ to 5μ in length, and 1.5μ to 1.7μ in width, averaging 4.5μ by 1.5μ (pl. 5, f. 2).

This species penetrates pine wood when inoculations are made, nearly as readily as *C. pilifera*. The mycelium in the wood cells follows the medullary rays in pine wood, but in red gum wood it penetrates also numerous tracheary vessels, and sometimes the wood fibres. It is most abundant, however, in the medullary rays of the latter wood.

Ceratostomella minor, n. sp.

During the year 1905 some specimens of pine wood stained with a dark blue color, from *Pinus Arizonica* Eng., were received from Dr. A. D. Hopkins. From these there were isolated two species of wood-staining fungi; one a species of *Ceratostomella*, the other a *Graphium*. The *Ceratostomella* proved to be smaller than the species from *Pinus Virginiana*, and differed in other points. The fungus gained entrance through the galleries of wood beetles, the stain radiating from cavities made by these insects. When grown in pure culture the fungus possessed conidia and ascospores. As the specific characters do not agree with any previous description of *Ceratostomella*, the name

C. minor is assigned, with the following cultural characters: —

Mycelium.

Cultures of either conidia or ascospores on pine agar media germinated in a few hours, and in two days the colonies began to form conidia. The mycelium is white and sparse. The hyaline filaments of the conidial stage measure in width 1.5μ to 2.6μ, averaging 2.3μ. The brown or black filaments in agar cultures and in wood measure in diameter from 2μ to 4μ, averaging 3.5μ. These are often rugose, the roughenings being coarser than those in *C. exigua*. In some portions of the mycelium on wood there are filaments that contain cells that are unequal in diameter, being enlarged at one end. Like *C. pilifera* this species follows chiefly the medullary rays of pine wood.

Conidia.

The formation of the conidia and the form of fruiting do not differ essentially from those of *C. pilifera* and *C. exigua*. The unicellular, hyaline conidia measure from 4μ to 5.5μ in length, and from 1.8μ to 2μ in width, averaging 4.5μ by 2μ. They are oval to elliptical in shape, and fall off at the slightest touch, collecting in rounded masses on the hyphae when in moist air.

Perithecia.

The perithecia mature in about three weeks in artificial cultures. They are spherical, black rugose bodies, varying from 40μ to 70μ in diameter, averaging 52μ, with a beaked ostiolum 120μ to 160μ in length, averaging 135μ, and from 6μ to 12μ in diameter (pl. 5, f. 6). The beak ends in a whorl of short, thick bristles (pl. 3, f. 4). The asci are round to oval, hyaline, with eight spores in each, usually arranged in fours (pl. 5, f. 7). The spores measure 3.1μ to 4.2μ in length and .9μ to 1.9μ in width, averag-

ing 3.5μ by 1.5μ. They are hyaline and germinate terminally.

The perithecia are smaller than those of *C. exigua*, the description of which follows; the ascospores differ in shape, and are smaller, and the terminal bristles of the beak have a different shape, being short and thick as compared with the slender ones of *C. exigua*.

Ceratostomella exigua n. sp.

The wood of dead and dying trees of *Pinus Virginiana* Mill., and one or two other species, is often colored a blue-black color, even more intense than that produced by *Ceratostomella pilifera* in wood of the western yellow pine. Specimens were first obtained for study from Dr. A. D. Hopkins of the United States Department of Agriculture. It was at first thought that the stain was caused by *C. pilifera*, but pure cultures of the fungus proved that it was different in a number of particulars. The scanty mycelium, the numerous diminutive perithecia and the smaller conidia, as well as the more intense color of the stain, were prominent points of difference which were considered of specific importance. These characteristics remained quite constant through a series of cultures on various kinds of wood.

The life history of the fungus obtained from a series of pure cultures is as follows: —

Mycelium.

Cultures grown on pine decoction agar from both conidia and ascospores give in a short time colonies with a white mycelium much more limited in growth than that of *C. pilifera*. The conidial stage appears after 24 hours, and is of the same type as that of *C. pilifera*, but with the conidia in lesser numbers. In a few days the perithecia appear on a mycelium which assumes a very dark brown,

almost black, color. The development of the fungus on wood is slower than that of *C. pilifera*, staining pine, oak, elm and ash with a blue-black discoloration contrasting sharply with the unstained portions. The mycelium penetrates pine wood through the medullary rays, and in some cases enters the wood fibres. The hyphæ of the hyaline mycelium bearing conidia average 2.5μ in diameter, while the dark brown filaments in wood measure from 2μ to 6μ, averaging 4μ in diameter. On the surface of wood in the vicinity of perithecia some filaments have swollen cells. Many of the filaments in wood cells have fine transparent roughenings all over the surface.

Conidia.

The conidia, like those of *C. pilifera*, are borne in whorls of single spores and short moniliform chains intermingled (pl. 6, f. 4, 5). In older cultures they drop together in clusters resembling somewhat those of *Cephalosporium*. They are oval to elliptical in shape, one-celled, hyaline, and vary in size from 3.5μ to 4.5μ, in length, and 1.6μ to 2.2μ in width, averaging 4μ by 2μ (pl. 6, f. 6).

Perithecia.

In artificial as well as in natural growths, the perithecia are very abundant. They are formed in large numbers under favorable conditions after 10 to 14 days. The process of formation is similar to that of *C. pilifera*. The perithecia are globose. They are black, brittle, with a roughened surface. They measure 60μ to 80μ, averaging 73μ in diameter, with a beaked ostiolum 150μ to 200μ in length, and 8μ to 18μ in diameter, averaging 180μ by 14μ (pl. 3, f. 2). The asci are hyaline, irregularly oval to elliptical, and contain 8 spores, often arranged in fours. The ascospores are hyaline, elliptical, sometimes slightly curved, and measure 2.1μ to 2.8μ in length, and .8μ to 1.1μ in width, averaging 2.5μ by 1μ (pl. 6, f. 7). The sacs usually disappear before the spores are ejected.

This species resembles the description of *C. microspora* E. and E. but differs in the shape of the ascospores, the size of the perithecia, and the length of the beaks. It has, in addition, a conidial stage, which serves to further set it apart as a new species. On account of the minuteness of its perithecia and spores it is named *C. exigua*.

Ceratostomella moniliformis n. sp.

Another species of *Ceratostomella* was found by Dr. von Schrenk growing on gum wood in Texas, near Kirbyville, occurring on *Liquidambar Styraciflua*. This species stains the wood of gum a brown color, and is the most rapid growing form studied. It is distinct from the other species of *Ceratostomella* in the form of the conidial clusters, and in the early color of the mycelium. The perithecia are covered with short spines, otherwise resembling very much those of *C. pilifera*. The name *Ceratostomella moniliformis* is given to the fungus, with the following cultural characters:—

Mycelium.

Cultures of either conidia or ascospores sown in agar plates germinate quickly, and in 24 hours produce the conidial stage. In two or three days the perithecia are produced. The colony is hyaline at first, but in a few hours begins to turn gray, and finally becomes black. The mycelium is coarsely granular, the filaments measuring 2μ to 8μ in diameter.

Conidia.

The conidia are found on simple or branching, upright hyphae, both in simple moniliform chains and in terminal clusters, the latter resembling the form occurring with some species of *Graphium* (pl. 5, f. 3, 4, 5). They are formed by the abstriction of the ends of the hyphae, and often fall together as fast as they mature, in rounded

masses, surrounded by either water or mucilage. They are unicellular, cylindrical in shape, hyaline, and measure 6μ to 8μ by 1.8μ to 2.2μ, being of different shape and dimensions from the ascospores, and are thus easily distinguished from them under the microscope. The conidia in mass as they become old have a gray color.

Perithecia.

The perithecia are formed by the union of two or more filaments of the mycelium. First, a gray mass of irregular cells appears at the point of union. This rapidly develops into a globular perithecium, from the top of which there is then rapidly thrown out a beaked ostiolum, consisting of parallel filaments. The perithecia are brown to black in color, 90μ to 180μ in diameter, covered with sparse, conical spines, 12μ to 16μ long, with a diameter of 6μ at the base. The beaked ostiolum is brown to black throughout its length, striate, and is surmounted by short, rather thick, hyaline bristles, measuring 12μ to 18μ by 2μ (pl. 3, f. 5). When the perithecia are mature, the ascospores are ejected in water in long, slimy, gray masses. In nature they are ejected in an irregular gray mass supported by the terminal filaments of the beak. The asci are fugacious, hyaline, oval, and average 20μ by 10μ. The ascospores are hyaline, not guttulate, at least at first, oval, often flattened on one side, measuring 4μ to 5μ by 3μ to 4μ.

This species of *Ceratostomella* is so different in color from the other species studied as to suggest that it may be a *Ceratostoma*. The gray color of the mycelium on media in which the mycelium of other species remains hyaline, the constant tint of gray in mature conidia and ascospores, and the peculiar moniliform chains of conidia very distinctly set this form apart at least as a very distinct species. But since the color of the spores shows only in mass, it is

thought best to place the species at present under *Ceratostomella*.

II. WOOD-BLACKENING AND WOOD-BROWNING FUNGI.

1. Graphium.

Graphium has been associated with the decay of wood and other organic matter ever since the original species were named by Tode * and Corda,† and placed under *Stilbum* by Corda. It has been found also to be associated with the staining of lumber, especially of pine and gum boards. It has been isolated from black or brown stained portions of wood taken from *Pinus*, *Populus*, *Liriodendron*, *Liquidambar*, *Quercus*, *Acer* and *Wistaria*. Species of this genus, like those of *Ceratostomella*, enter most kinds of wood through the medullary rays, being usually confined to the sapwood, with the exception that they may grow upon decayed heartwood that other fungi have previously attacked. In the study of a number of species of *Graphium* not all species stained wood alike: some scarcely stained the wood at all, others, like the one from *Liquidambar*, are quite effective as wood stainers.

The stain given by *Graphium* varies from a dirty gray to a dark brown, or, rarely, a black color.

The genus *Graphium* was first described by Corda. It is described as follows, using a free translation: — "Stroma cylindrical, clavate, or capitate, brownish, rather rigid, the upper hyphae paler, lax, and bearing the conidia, which are elliptical or oblong, hyaline, often involved in mucus at first." No mention is made either by Saccardo,‡ or Engler and Prantl‡ of any conidial stage other than that found on the stroma or head.

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* Tode. Fungi Meckl. **1**: 10. † Corda. Icon. Fung. **1**: 8.

‡ Saccardo, P. A. Michelia. **2**: 32; Syll. Fung. **4**: 564, 609.

‡ Engler, A. and Prantl, K. Die Natürlichen Pflanzenfamilien. **1**: 493.

Boulanger * has proven by the use of careful cultural methods that *Sporotrichum chlorinum* Link var. *grisea* Boul. is a stage of *Graphium eumorphum* Sacc. This discovery is now verified by the present investigation, and *Sporotrichum*-like stages of other species of *Graphium* are now published for the first time. Boulanger also discovered a *Sporotrichum* stage of *Chaetomium cuniculorum*, and obtained fruits of the latter fungus in connection with *Graphium*, indicating that *Chaetomium cuniculorum* is the perfect stage of the other two fungi. We have not been able to verify the latter relationship.

Graphium giganteum (Pk.) Sacc. is given by Durand † as a conidial stage of *Holwaya gigantea* (Pk.) Durand.

Zopf ‡ observed a moniliform conidial stage of *Chaetomium* which failed to germinate. He makes no mention of finding any related forms of *Sporotrichum*.

Some of the species we have studied contain both *Sporotrichum* forms and moniliform fruits, the latter resembling very much the branching clusters of the conidial stage of *Ceratostomella*.

From the study of several species of *Graphium* the following cultural characters are found to be common:—

Mycelium.

The mycelium in a culture from either of the two spore-forms found in the species studied is from the first hyaline and septate. On rich vegetable-decoction agar, like that made from green pine sapwood, bean pods, potato, etc., a fluffy white mycelium is usually produced, varying in density with the medium and the species. The first form of conidia is borne on erect hyphae, which may be either simple or branched. These hyphae or conidiophores

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* Boulanger. Rev. Gén. de Bot. **1895**: 97–102.

† Durand, E J. Bull. Torr. Bot. Club. **28**: 351. (1901).

‡ Zopf, W. Ueber Pilzfarbstoffe. III. Bot. Zeit. **47**: 86–89. (1889).

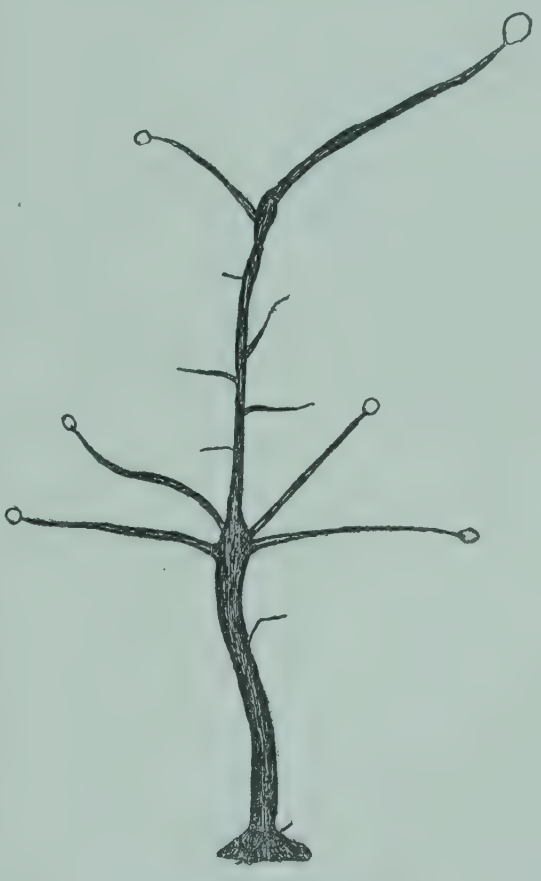
branch alternately from the mycelium. These first conidia are borne in clusters of three types, two of which are simple clusters of the type of those of *Sporotrichum* but not borne on prostrate hyphae, the other being a form which is like most of the conidia described under *Ceratostomella*. In this latter form the conidia are borne in the short branching chains. These conidia are all ephemeral and do not hold their vitality as long as those which are produced later upon the heads or stromata. In order to distinguish them from the latter, they are now for the first time called secondary conidia; and those of the heads or stromata are now called primary conidia. As the colony grows older, some portions of the mycelium become more or less pigmented, and the darker filaments grow together in masses from which erect columns of parallel hyphae spring forth. These bear heads composed of branched hyphae, which produce the primary conidia terminally by abstriction. As fast as the conidia are formed they drop away into a mucous matrix which forms over the surface of the head.

Secondary Conidia.

The secondary conidia of the *Sporotrichum*-type are of two forms and are borne on simple erect or branched hyphae. The first form of this type are attached to the hyphae in spreading, open clusters, which do not fall together in masses until some days after they mature (pl. 7, f. 3). The second form are produced in close clusters which fall together as rapidly as they mature (pl. 9, f. 9). The third form of fruiting, as mentioned in the previous topic, more nearly resembles the branching chains of the conidia of many species of *Ceratostomella* (pl. 9, f. 3). The spores in all three forms are oval, elliptical, or cylindrical, and correspond closely in form and measurement to the primary conidia of the same species. They are unicellular and formed by abstriction either from the terminus of the hyphae or from short, terminal or lateral branches.

Primary Conidia.

After the primary conidia have been detached and separated from the mucus there is in many species nothing to distinguish them from the secondary conidia. In fact, the real difference usually in the two forms is whether they are borne on a single hypha, or on hyphae united in a stroma. The agglutinated cluster on a single stalk of one hypha corresponds morphologically to the mucous-covered head (pl. 7, f. 2, 5). The latter are more persistent, and retain the conidia for a much longer time. A secondary growth of the stromata has been noted in some species after the first spores have been formed, and have dropped away, in which there are formed branches from the end of an old stalk, growing out from the apex. (See figure). Each of these subsidiary stalks is composed of a number of parallel filaments, or hyphae, which in turn branch at the outer ends and form masses of conidia like the original head, only smaller. Such growths take place on rich, starchy media like cooked potatoes. On cultures on rice and potato an abortive type of stromata is often formed in the shape of somewhat flat, branching stalks, which grow much taller than the fruiting form, but bear no conidia. This abortive form resembles very much the original description of the sterile fungus *Anthina* Fr., which is probably a form of *Graphium*.



G. EUMORPHUM, × 50.
Proliferation of stroma.

In the gross appearance of artificial cultures of *Graphium* and of *Ceratostomella* there is often a striking resemblance or mimicry. The secondary conidial stage of the former resembles superficially the conidial stage of the latter, and the mucous head of the former that of the perithecial stage of the latter at the time the ascospores are ejected in a viscid drop. The mucus surrounding the conidia of *Graphium* is soluble in water; on the other hand, the jelly-like substance exuded from the perithecia of *Ceratostomella* is very difficultly soluble in water. Both are well adapted for adhering to the bodies of insects with which they come in contact.

Perfect or Chaetomium Stage.

The *Chaetomium* stage of *Graphium* observed by Boulanger has not been found in connection with the species studied; but as the cultural work on *Graphium* has not yet been concluded, it is hoped that by the use of the proper culture media some species may finally be stimulated to produce perfect forms, either of *Chaetomium* or other genera.

In the consideration of the species of *Graphium* studied, it is thought best to separate them into the following groups based on the form of fruiting in the secondary conidial stage: —

A. Species of *Graphium* with a secondary conidial stage with conidia resembling those of *Sporotrichum*.

B. Species of *Graphium* with a secondary conidial stage unlike *Sporotrichum*.

1. Species with secondary conidia borne continuously and terminally, falling at once in clusters.
2. Species with secondary conidia borne either in simple clusters or in clusters of short branched chains.

A. Species of Graphium with a secondary conidial stage with conidia resembling those of Sporotrichum.

Graphium ambrosiigerum n. sp.

A species of *Graphium* was found growing in the galleries of wood-boring beetles in the wood of *Pinus Arizonica* Eng. This material was furnished by Dr. A. D. Hopkins in connection with the study of the relation between ambrosia fungi and ambrosia beetles, a subject which is still under consideration in connection with the study of such beetles by Dr. Hopkins. Pieces were taken from the stained wood in the interior of the block near a gallery, and placed in test tubes of pine sapwood, which had been sterilized after being moistened. From the mycelium in the stained wood there grew out a white growth, bearing at first the secondary then the primary conidia of *Graphium*. Secondary conidia were found in some of the galleries when the material was first examined, but were not recognized as such at the time. The following are the cultural characters of the fungus:—

Mycelium and Secondary Conidia.

When cultures are made with either the primary or secondary conidia on pine decoction agar, the spores generally germinate in a few hours, and in two or more days colonies may be noted with a white, sparse mycelium. At this stage of growth, secondary conidia appear of the *Sporotrichum*-type, borne on erect, simple hyphae (pl. 8, f. 5). These are hyaline, and oval in shape. After a few days, portions of the mycelium assume a brownish color, and from certain matted masses of filaments or stromata there grow out tufts of erect, parallel hyphae (pl. 8, f. 6).

These tufts of hyphae elongate into a long, round stalk, terminating in a bunch of either verticillate or alternate branches.

Primary Conidia.

The primary conidia are formed on the upper portion of the stroma or head by an abstriction of the ends of the hyphae (pl. 8, f. 7). They are formed continuously, and as soon as mature, fall away into the mucous mass which surrounds the head. The mass is hyaline at first, changing, as it grows older, to a straw color, and finally to a dark brown. The stalk is usually hyaline in the first stages of its growth, but later becomes almost black at the base, shading off to a light brown near the apex, with a striated appearance. No chlamydospores or sclerotia are formed. At first the stroma is simple, but by the addition of branches from the base becomes gregarious (pl. 8, f. 4).

The following are the measurements of the mycelial structures: the hyaline mycelium measures from 1.5μ to 2.5μ in diameter, averaging 2μ. The colored portion averages in diameter about 4μ. The secondary conidia measure 3.5μ to 4μ in length, and 1.2μ to 1.5μ in width, averaging 3.7μ by 1.3μ. The primary conidia average 5μ by 3μ. The stalks average in length from 500μ to 900μ. The head, including the mucous drop, measures on an average 200μ. These do not agree with any previous description of species of *Graphium* and the fungus is here named *Graphium ambrosiigerum*, owing to the relation of the conidial stage to ambrosia beetles.

Cultures were made on a number of kinds of wood. The fungus grew readily in the sapwood of pine, gum, oak and ash, bearing in most cases numerous heads. Secondary conidia are usually formed in abundance. Cultures on the heartwood of these trees produce little or no growth of the fungus. Light colored wood is stained a color varying from a dirty gray to a light brown, or almost black.

The mycelium penetrates pine and other similar woods through the medullary rays, dissolving the starch. In gum wood, *Liquidambar Styraciflua* Linn., it penetrates in addition many of the vessels of the wood. As compared with *Ceratosomella* the penetration is not so rapid, neither is the stain so intense; but on the other hand it may in time stain wood as deeply.

Graphium eumorphum Sacc.

A species of *Graphium* has been found frequenting the old wood of *Rubus strigosus* and related species. This was isolated and grown first on wood of several kinds which it was found to stain lightly, then upon agar media. An examination of the cultural characters of the fungus place it readily under *Graphium eumorphum* Sacc. The following description gives the principal characters, from both natural and artificial cultures:—

Mycelium.

Cultures made from both the primary and the secondary conidia produce a sparse, white mycelium, which soon turns a gray-green, and whose filaments measure from 1μ to 2μ in diameter. These soon bear numerous conidia of the *Sporotrichum*-type (pl. 7, f. 2), and about a week later the stromata or stalked heads of *Graphium* appear (pl. 7, f. 1). The heads are white, changing to a green or greenish yellow, and measure with the mucilage drop from 30μ to 100μ. The stalks vary from a yellow to a dark olive or a brown color, and measure from 300μ to 500μ in length, and from 10μ to 40μ in diameter.

Secondary Conidia.

The secondary conidia are obovate to elliptical in shape, and average 7.8μ by 3.4μ (pl. 7, f. 3). They are borne,

unlike *Sporotrichum*, on simple erect not prostrate hyphae. This stage nevertheless is apparently identical with *Sporotrichum vellereum* Sacc. and Speg. var. *grisea* Boul.

Primary Conidia.

The primary conidia are borne on branching hyphae in stalked heads (pl. 7, f. 5), and average 7.7μ by 3.4μ. They are of a light green or yellow tint, and are identical in shape and appearance with the secondary conidia.

Graphium atrovirens n. sp.

In addition to *Graphium smaragdinum* on the red gum wood a new species was found present in a number of instances. This discolored the wood with a brown stain, similar to the latter species, and at first was not distinguished from it, having the same color and appearance in mass; but after a more careful study of the colonies on agar, different forms of secondary conidia were found present in two types of colonies, making it necessary to separate this form from *G. smaragdinum* and giving good reasons to call it a different species. It is now named *Graphium atrovirens* with the following as its cultural characters:—

Mycelium.

The growth of the colonies on agar plates is fluffy, as compared with that of *G. smaragdinum*. This is due to the formation of strands in the mycelium by the union of a number of parallel filaments, these growing upward and often forming large branching masses, similar to those formed by the mycelium of some species of *Cerastostomella*. The filaments of the mycelium are hyaline at first, later changing to dark green or olive, in the vicinity of the stromata or heads. They measure 3μ to 4μ in diameter. Those which unite to form the stroma usually measure but

2μ in diameter. The color of the stroma is dark green to black when mature, but in growing colonies all variations between hyaline and dark green may be found. The stalks measure from 1.5 mm. to 3 mm. in height, and 8μ to 80μ in diameter, being proportionately more slender than those of every other species of *Graphium* described in this paper (pl. 8, f. 1). In this species, as in others, all the forms of gradation between a head with a stalk composed of one filament, and a stalk with many filaments may be found. The difference between those bearing secondary conidia and those bearing primary conidia consists mainly in the absence of color in hyphae bearing the former.

Secondary Conidia.

The secondary conidia are borne in simple open clusters, of the type of the conidia of *Sporotrichum*. They are borne either terminally or along the sides of lengthened hyphae (pl. 8, f. 2, 3). They are obovate to elliptical in shape, measuring 4μ to 5.5μ by 1.6μ to 2μ. They are hyaline, becoming guttulate when old. The clusters remain open for a number of days after they are mature, but under very moist conditions fall together in rounded masses on the hyphae. The conidia of *G. smaragdinum* fall together as soon as mature, the clusters being much closer in their formation (pl. 9, f. 9).

Primary Conidia.

The primary conidia are borne terminally on the ends of the branching hyphae in the stroma which form large, mucilaginous heads. These, without the sheath of mucus, are flattened oval in shape, (pl. 8, f. 1), white at first, later gray in color. They measure 40μ to 600μ in their greatest diameter, the latter being the measure of the head including the mucilaginous sheath. The primary conidia are hyaline, obovate to elliptical, and measure

3.5μ to 4.5μ by 1.4μ to 2μ. The stalks in this species bearing the primary conidia are sometimes much branched, but this feature is dependent more upon the culture medium and physical conditions than upon the inherent specific tendencies. One difference between the stalks of this species and those of *G. smaragdinum* is that in the case of the latter they tend to be gregarious, and are more apt to be swollen at the base.

B. Species of Graphium with a secondary conidial stage unlike Sporotrichum.

1. Species with secondary conidia borne continuously and terminally, falling at once into clusters.

Under this subdivision will fall at least two species, *Graphium smaragdinum* and *G. rigidum*. A third species is still under culture but the work has not progressed sufficiently for identification.

It is a very difficult matter to determine the manner in which the secondary conidia are borne in these species, because as rapidly as the conidia are formed by abstriction from the end of simple or branched hyphae they break off and cling closely to the ends of the hyphae, being enveloped in a thin coating of water or soluble mucilage which hides the outline of the hyphae and conidia. It is probable that there is sometimes more than one conidium attached directly to the end of each hyphae branch and that these secondary conidia are but modified forms of those described in division A. The conidial masses formed are similiar in appearance to those of *G. ambrosiigerum*, *G. eumorphum* and *G. atrovirens*.

It is also quite probable that in all species of *Graphium* the primary conidia are formed in the head precisely as the secondary conidia are formed in the open and that the two

forms of conidia are morphological equivalents. In most of the species studied many gradations were found between a head on a stalk of a single colored filament and heads on stalks of two to many filaments.

Graphium smaragdinum (A. & S.) Sacc.

The wood of the red gum, *Liquidambar Styraciflua* L., when freshly sawn and piled up, is very rapidly stained by the combined effects of a number of fungi. The most important among these are *Ceratostomella*, *Graphium*, *Hormodendron*, and *Dematium*. On the surface, especially on the sapwood, the fruits of *Graphium* appear more frequently than those of the other fungi, especially when the boards are placed in a moist chamber. *Graphium* was obtained from gum boards taken from a number of localities, and in most instances a species was found which resembled *Graphium rigidum* but differed from it in a number of its cultural characters. From the following characters, taken from both natural and artificial cultures, it corresponds more nearly to *Graphium smaragdinum* (A. & S.) Sacc., and it is assigned to this species.

Mycelium.

Primary and secondary conidia, sown in agar plate cultures, germinate in a few hours, and small, white colonies are visible in a day. The mycelium is abundant, floccose; the filaments are septate, hyaline at first, later changing to dark green, measuring from 2μ to 4μ in diameter. In two days secondary conidia appear, borne terminally on simple hyphae, (pl. 9, f. 9). In less than a week, on dark colored portions of the mycelium, the stalks and heads or stromata of the *Graphium* stage appear (pl. 9, f. 8). These are hyaline at first, changing as they age to dark green, then to black at the base, shading off to a light gray-green

at the top. The stalks vary in height from 1 to 2 mm., averaging 1.5 mm., with an average diameter of 25μ. The heads, when enveloped in mucus, are globular and measure from 40 to 600μ in diameter; without the sheaths they are flattened oval or fungiform, and measure 30μ to 200μ. They are colorless at first, but later change to gray or green. When a stalk is broken off before maturity, it often sends out small branches, either of single hyphae or of clusters of hyphae, bearing conidia.

Secondary Conidia.

The secondary conidia are usually elliptical in shape, and measure 3.6μ by 1.8μ, average. They are hyaline, colorless, and are borne both terminally in close clusters and on simple hyphae, and in a short time fall off and adhere together, thus forming miniature heads (pl. 9, f. 9).

Primary Conidia.

The primary conidia are elliptical in shape, and are borne terminally on branched hyphae (pl. 9, f. 10). They measure 3.8μ by 1.6μ, average. They are hyaline and colorless. In some cases, where the upper portion of the stalk or head has been broken off new stalks sprout out from the region of the apex in the old one. Branches are also formed without injury.

The fungus penetrates deeply into red gum boards, giving them a dirty appearance, rendering them unfit for making the best grade of boxes, crates, etc. It permeates the medullary rays and many of the larger and some of the smaller vessels of the wood. The mycelium in the wood is generally of a color varying from gray to brown or dark green.

Graphium rigidum (Pers.) Sacc.

A species of *Graphium* was found discoloring the sap-

wood of lumber made from *Quercus rubra* L. in Indiana. This, when isolated in pure cultures, grew readily on the sapwood of pine, oak, gum and ash, and on vegetable agar media, also on potato, bean, and other vegetables in test tubes. The fungus corresponds quite closely to the description of *Graphium rigidum* (Pers.) Sacc., with the exception that it has in addition a conidial stage, the conidial clusters taking the closed form. The following emended description of this species is now given from artificial cultures on wood and agar media: —

Mycelium.

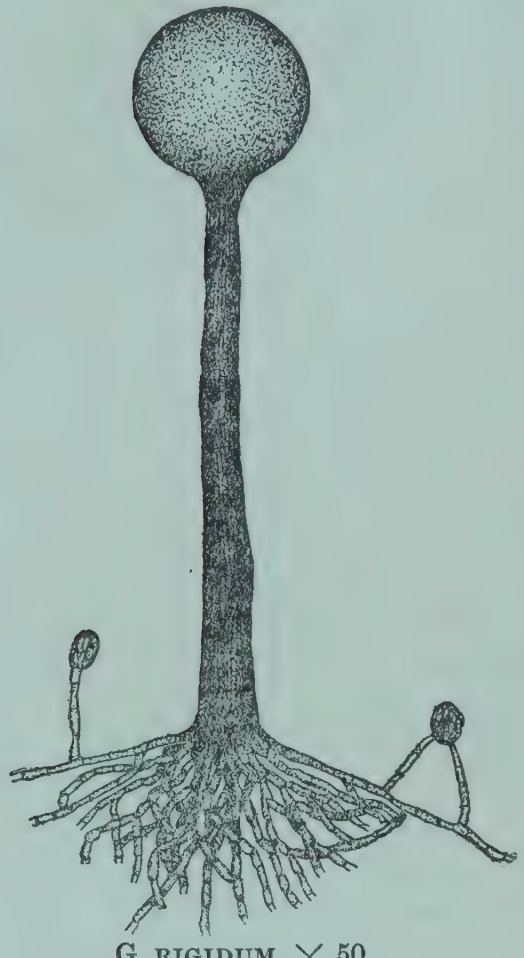
Cultures of both primary and secondary conidia sown in ordinary vegetable agar media germinate in a few hours, and in two days begin to bear an abundant crop of secondary conidia in clusters of a type similar to those of *G. smaragdinum*, which collect as rapidly as they develop into rounded, mucilaginous clusters (pl. 7, f. 7). The filaments of the mycelium are hyaline at first, but in a few days form a brown pigment in the older portion, and throw up stalked heads bearing the primary conidia. These vary from a stalk consisting of two or three filaments with a small globular or flattened oval head, to one consisting of many, with a much larger head (pl. 7, f. 6).

Secondary Conidia.

Secondary conidia are borne on both simple and branching hyphae by abstriction of the ends, and as fast as they are formed adhere together in masses resembling *Cephalosporium*. Theyare colorless, thin-walled, and are usually free from guttules and granules. They measure 3μ to 4.5μ by 1μ to 1.5μ (pl. 7, f. 8).

PRIMARY CONIDIA.

Primary conidia are elliptical, resembling in appearance and form the secondary conidia. They are hyaline, and measure 3.5μ by 1.5μ, average, in size (pl. 7, f. 9, 10). They are borne terminally on alternately branched, hyaline hyphae, and fall together in large, spherical, mucilaginous heads. The heads vary in color from a white to a dingy yellow. They measure, with the mucilaginous drop, 20μ to 500μ in diameter. The stalks vary from gray to brown or black, and measure from 1 mm. to 2 mm. in length, and 10μ to 40μ in diameter. They are usually solitary at first, but later may become gregarious, or even branched, especially in older cultures where a secondary growth has taken place.



G. RIGIDUM, × 50.
Stroma, with conidiophores.

In the study of this species several instances were noted where hyphae bearing the secondary conidia branched directly from filaments connected with the heads bearing the primary conidia, thus giving additional proof of the relation between the two forms of fruiting. (See figure).

2. Species with secondary conidia borne either in simple clusters or in clusters of short branched chains.

Graphium aureum n. sp.

The first species of *Graphium* differing in conidial forms

from the previous species was found on discolored boards made from the white pine, *Pinus Strobus L.* This stained the wood a light brown color, less intense than that made by any other species of *Graphium* investigated, with the exception of *G. eumorphum*. The constant presence of short chains in the formation of the secondary conidia was a character that needed the most careful verification, since it was possible that an admixture of *Ceratostomella* with the *Graphium* had taken place. This form of conidia was accepted as a fact only after careful study for six months, with repeated dilution cultures of both primary and secondary conidia in numerous agar poured plates and test tube cultures.

Another difficulty lay in the resemblance of the fungus to species of *Stilbum*, the stroma in its earliest stages being identical with species of this genus, owing to the absence of color. The same difficulty is to be found with others of the species studied. This indicates that the separation of *Graphium* from *Stilbum* on a color basis is not a good one, and that there is no good dividing line between the two genera. Should it be found that species of *Stilbum* have secondary conidia similar to those of *Graphium*, a better basis for generic separation would be found in the types of such conidia.

The following are the cultural characters of this species which is now named *Graphium aureum*:—

Mycelium.

In colonies grown on agar plates either from primary or secondary conidia there appear in two or three days secondary conidia borne singly or in branched chains from simple, erect conidiophores. These conidia are like those of *Sporotrichum* and of *Ceratostomella*. The mycelium is hyaline at first, changing to yellow, then to light brown. The filaments measure from 2μ to 3μ in diameter.

Secondary Conidia.

The secondary conidia are borne at first in loose, open clusters which, after standing for a few days in moist air, fall together in rounded masses, adherent to the terminus of the conidiophores (pl. 9, f. 6). They are hyaline, obovate to club-shaped, and are not guttulate except when old. They measure 4μ to 8μ by 1μ to 2μ, averaging 5μ by 1.8μ.

Primary Conidia.

The stalks or stromata bearing the heads of primary conidia are white at first, changing to a yellow color, and often to a dark brown at the base (pl. 9, f. 5). They measure 50μ to 750μ by 10μ to 90μ, and are composed of parallel filaments measuring 1μ to 2μ in diameter. These bear conidia terminally which are held together by mucilage in a flattened, oval head, which is white at first, then creamy yellow, finally a light brown when old and dry. The primary conidia are hyaline, obovate, and measure 4μ to 5μ by 1μ to 2μ (pl. 9, f. 7).

In cultures on rice and potato tubes tall *Anthina*-like, sterile, branching stalks, or stromatal outgrowths of a light brown color from 1 mm. to 4 mm. in height, are formed. These are very plainly abortive fruiting organs.

Graphium album (Corda) Sacc.

A species of *Graphium* was found growing on the wood of the beech, *Fagus atropunicea* (Marsh.) Sudworth. This discolored the wood a brown color. It was found to be a species resembling *G. aureum*, but sufficiently distinct to be separated from the latter species. A culture was sent to Mrs. Flora Patterson, Mycologist of the Bureau of Plant Industry, Washington, D. C., who identified the fungus as probably *Graphium album* (Corda) Sacc., a species which

is imperfectly described. The fungus is now assigned to this species with the following emended description taken from cultural characters: —

Mycelium.

The growth of colonies from both primary and secondary conidia is much like that of *G. aureum*. The colonies remain hyaline for some time; even the stalked heads show an absence of color for several days after their appearance. Finally the mycelium assumes a gray color, often with a green tinge, and at the same time the stromata assume a darker color. The filaments measure 2μ to 3μ in diameter.

Secondary Conidia.

The secondary conidia are of the type of branching chains, resembling *Ceratostomella* (pl. 9, f. 2, 3). They are obovate to cylindrical, hyaline, and measure 4μ to 6μ by 1μ to 2μ. The conidial clusters are open at first, but in moist air fall together after a few days, forming rounded masses on the ends of the hyphae.

Primary Conidia.

The stalks bearing the heads are hyaline at first, changing to a gray, finally to brown or black at the base. They are often much swollen at the base, and measure from .3 mm. to 2 mm. in length by 30μ to 300μ in diameter. The heads are large and showy, often much flattened, or even recurved at the edges, and measure 20μ to 600μ in width (pl. 9, f. 1). Their color is white at first, changing later to a creamy yellow color. The primary conidia are borne continuously on branched hyphae from the ends of the filaments in the head, falling off rapidly as they are formed, into the mucous mass which surrounds the head. They are hyaline, and measure 3μ to 5μ by 1μ to 1.5μ (pl. 9, f. 4).

2. Hormodendron.

An intense black color in irregular blotches often occurs on new pine, elm, ash, gum, oak, and other kinds of lumber, when sawn under a moist condition, during warm weather. A large number of such spots were examined, and the fungi present isolated for investigation. Species of *Hormodendron*, *Hormiscium* and *Alternaria* were found present. Two species of *Hormodendron* were identified, viz: *H. cladosporioides* (Fres.) Sacc. and a species not agreeing with any description previously published, and which is here given the name *H. griseum*.

Inoculations of these two species were made upon pine, elm, oak, ash and gum wood. Both species were found to produce superficial black stains, but neither penetrates deeply into hard woods. On the other hand, either species penetrates deeply boards made from the red gum tree, *Liquidambar Styraciflua* L. Under the microscope the conidial clusters of the two species closely resemble each other, but in cultures the gross appearance of the colonies is constantly quite different, the former varying from a yellow-green to a dark olive, or almost black, the latter from a light gray to a color approaching black; other differences were noted in the length of the conidiophores and of the conidial chains.

Hormodendron cladosporioides (Fres.) Sacc.

The species of *Hormodendron* most commonly found on boards is described here from artificial cultures, and assumed to be *H. cladosporioides*. Two other species occurring on wood, which have been previously described, but at a later date, are *H. atrum* Bon. and *H. elatum* Hartz. From the description of these two latter species it would be very difficult to separate the one from the

other, or either of them from *H. cladosporioides*. The description of our fungus might fit any of the three, but as the last named species is the older, its name will hold valid.

The following cultural characters were obtained from a large number of cultures on agar media, most of which were made from pine-decoction alone, or from the juices of vegetables combined with a pine-decoction:—

Mycelium.

Conidia sown on agar plates germinate and produce small, gray colonies visible to the eye in 24 hours. In three to four days the colonies begin to send up erect sporophores, bearing clusters of short septate branches, which are often branched again and from the ends of which branched chains of olive-colored conidia are formed (pl. 10, f. 1). The younger portions of the colony assume a yellow-green color, which rapidly changes to an olive, and finally to an almost black color, while the surface has a velvety appearance. The filaments are coarsely granular in the older portion, and are often constricted at the point of septation. They measure 2 to 8μ in diameter. The sporophores measure 100μ to 400μ in length, and 3μ to 4μ in diameter; the branches are 1- to 2- rarely 3- septate, and measure 6μ to 15μ by 3μ to 5μ.

Conidia.

The conidia are borne in simple chains of 2 to 6, rarely more; they are not granular or guttate except when old, and vary in shape from a blunt to a pointed oval. They measure 3μ to 7μ by 2μ to 4μ. When mature, both the hyphal branches and the conidia are of a dark olive color.

The work of Planchon* indicates that *Hormodendron*

* Planchon, Louis. Influence de divers milieux chimiques sur quelques champignons du groupe des Dématiées. Annales des Sciences Naturelles. Botanique. **11**: 1-256. *pl. 1–4.* (1900).

cladosporioides (Fres.) Sacc. and *Cladosporium herbarum* Link are identical. In some of our cultures forms intermediate between the two, and identical with the latter, were present (pl. 10, f. 1), but in no case were septate conidia noted, such as are given in the description of *C. herbarum*, the septation being confined to the hyphae which bear the conidia. If, however, the modified hyphal branches be mistaken for conidia, it is easy to assume them to be the septate conidia of *Cladosporium*. Time was not had to apply all the culture methods and media of Planchon to our species. Enough of the forms described by him in his study of these two fungi have been found in our cultures to verify his work; but the question still remains as to whether he is correct in assuming the fungus to be a *Cladosporium*. This hinges upon whether the conidia-like branches bearing the conidia may themselves function as conidia; but even this might not settle the question, since it is a well-known fact that in most of our imperfect fungi any portion of the young mycelium when broken up may be able to reproduce the fungus. This being the case, we will for the present use the name *Hormodendron* here to designate our plant.

Hormodendron griseum n. sp.

The other species of *Hormodendron* studied was found growing on the wood of *Liquidambar Styraciflua* L., *Pinus echinata* Mill., and *Fraxinus Americana* L. The colonies of this species on both wood and agar media were of greater height, and of a different color when mature, as compared with those of *H. cladosporioides*. The mycelium is often hyaline, or nearly so in many portions, giving the colony a gray appearance, even though the conidial clusters are of a dark olive color. These two species of *Hormodendron* were grown carefully for nearly a year in parallel sets of cultures, with no reversion of the one type to the other,

which was looked for. The following description of *H. griseum* is made from cultures grown on the same media from which the characters of *H. cladosporioides* previously given were obtained:—

MYCELIUM.

The conidia of this species germinate readily, and similarly to those of the preceding species, but the colony is a day or two longer in producing conidia than that of the former species. The habit of fruiting is the same, but the conidia are borne in longer chains. The mycelium is coarsely granular, and thick-walled in the older filaments, which measure from 3μ to 10μ in diameter. The sporophores or fruiting hyphae measure 200μ to 800μ in length, and 3μ to 4μ in diameter. The hyphal branches are in two series, and are from 1- to 3- septate, measuring 6μ to 14μ by 3μ to 4μ.

CONIDIA.

The conidia are borne in branching chains of 2 to 10, and are formed from the ends of the hyphae by abstriction (pl. 10, f. 2). They are of a sooty color, pointed oval, and measure 3μ to 6μ by 2μ to 4μ.

3. HORMISCIUM.

Hormiscium gelatinosum n. sp.

In the study of the black stain of pine, elm and red gum boards at least one species of *Hormiscium* was found causing a very intense black stain, especially in sapwood. It is with some hesitancy that this fungus is named *Hormiscium* in view of the great resemblance of the mycelium on agar plate cultures to some of the forms of *Dematium pullulans* de Bary, found by Planchon* in his study of the

* Planchon, Louis. *l. c.*

latter fungus, and related fungi. The finding of chains, or round conidia borne in chains, on short hyphae (pl. 11, f. 7), and the identification of the fungus as *Hormiscium*, by Mrs. Flora Patterson, has led to the placing of the species under the genus *Hormiscium*. This form differs from other species of *Hormiscium* in its gelatinous nature and dimorphous conidia, and is now called *Hormiscium gelatinosum*, with the following cultural characters: —

The fungus grows readily on many kinds of media, especially upon agar media from vegetable decoctions, upon various substances containing starch, and upon the sapwood of pine, oak, gum, and other trees. It makes only a scanty growth on the heartwood. On potato and rice tubes it covers the surface with a black, shiny growth of slimy, matted filaments.

Mycelium.

When conidia of either form are sown on agar plates the colonies which result resemble very much those of some yeasts and bacteria. The growth of the colony is slower than that of most fungi. The form of the colony is variable. Where the conditions are not favorable the colony is rounded, cream-colored, mucous, growing with a roughened surface and a wavy edge. In more favorable conditions, on better media, etc., the edge of the colony becomes fimbriate or toruloid (pl. 11, f. 4). The shape of the colony thus apparently depends directly upon the conditions under which it grows. The filaments of the mycelium are fewer in relative proportion to the bulk of the colony in the younger forms than in the older forms. In older colonies, near the edge, filaments predominate. They are toruloid in form, the cells are very irregular in shape, varying from long, cylindrical, almost hyaline cells (pl. 11, f. 7), to beaded forms (pl. 11, f. 8) of a dark olive color. The former vary in diameter from 2μ to 8μ; the latter,

from 5μ to 10μ. The latter form are of the nature of chlamydospores, having thick walls, and from one to two cells. These sometimes germinate, and apparently may function as resting spores.

Conidia.

Two forms of conidia are borne on the mycelium, one of these being the hyaline form (pl. 11, f. 5), which buds both from the cells of the mycelium and from other conidia during the earlier growth of the colony. These are deeply imbedded in mucilage, and germinate readily, if not too old, in agar plate cultures. They are ephemeral, losing their power of germination in a few weeks. They are elliptical in shape, and measure 8μ to 12μ by 3μ to 5μ, and are rarely septate. Among the hyaline conidia, as the colony grows older, brown forms of the same shape soon occur (pl. 11, f. 6), and finally become very abundant. These are thick walled, and do not appear to germinate as readily as the hyaline type. They probably function as resting spores. They are sometimes septate, but more often have one cell. They measure 10μ to 14μ, by 5μ to 6μ. Another form of conidia of the true type of *Hormiscium* (pl. 11, f. 7) is found borne from the filaments in the older portions of the extremities of the colony, and on the filaments in cultures upon wood. These are globose in form, of a dark olive color, not rugose, and are borne from short hyphae in chains of two to several. They measure from 7μ to 12μ in diameter. These chains hold together tenaciously, and do not break apart like those of related genera.

4. Other Wood-blackening Fungi.

A number of other fungi were noted, which add to the stains which occur superficially on lumber, especially on the sapwood. Several of these were identified, which apparently discolor the wood only by the color present either

in the mycelium or the fruiting bodies. None of them are considered as important in their effects upon the value of the lumber, as the mycelium does not penetrate deeply into the wood. Those identified were: *Alternaria tenuis* Nees, *Stachybotrys alternans* Bon., *Chaetomium* sp., *Aspergillus niger*, *Stemonites* sp., and *Gliocladium* sp.

III. WOOD-REDDENING FUNGI.

1. Penicillium.

The fact that *Penicillium* might stain wood was brought to our attention during the year 1903. Some cultures of *Ceratostomella exigua* were contaminated with a lemon-colored fungus, which, under certain conditions, stained the wood an orange red color. Upon isolation it was found to be a *Penicillium*, which was dimorphous, having a fertile mycelium with gray-green colored fruiting clusters, and a sterile mycelium which assumed either a lemon color or an orange red color, varying with the reaction of the medium upon which it was grown, the former color being present on acid media, and the latter on alkaline.

This led to the study of *Penicillium* from various sources, and from different kinds of wood. Some were found to stain pine sapwood, under certain conditions, an orange red color, others a crimson red, and still others, a color intermediate between the two. At least three species of *Penicillium* were found which were proven to stain wood. These were often intermingled, sometimes with each other, and at some times with *Fusarium*. This complicated the problem, and the difficulty was further increased by the fact that it is hardly possible to name correctly the color-producing species of *Penicillium* without a long series of cultures. The investigations of Dierck *

* Dierck, F. Essai de révision du genre *Penicillium*. Ann. de la Soc. de Brux. 1901.

and that of Thom * have shown that even when the form characters of two forms of *Penicillium* are alike, there may be distinct differences in the color of the fungus on certain different kinds of media. The former has made a revision of the genus *Penicillium*, based chiefly on physiological characters, but also taking into consideration the strictly morphological. The latter in studying the species of *Penicillium* which were found concerned in the ripening of the various kinds of cheese found great difficulty in naming them, owing to the fact that what may be morphologically the same species may not have the same effect on the chemical properties of freshly made cheese, owing to varying action of different strains or races of *Penicillium* on the organic compounds present.

Penicillium aureum Corda.

Of the two species of *Penicillium* studied, the most common was identified finally as *Penicillium aureum* Corda. It is dimorphous, as has already been mentioned, and is one of the common species found on pine wood. It was also found in cultures from gum, oak, and other woods. A culture sent to Mrs. Flora Patterson was identified as *P. aureum*, thus verifying our observation.

This species grows readily on the fresh sapwood of our most common forest trees, upon bouillon, and various vegetable decoction agar media, upon potato, starch, and other similar substances. The following cultural characters are taken from both natural and artificial cultures.

Mycelium.

Cultures upon agar media develop rapidly from conidia, the mycelium usually becoming visible within a day as a

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* Thom, C. Some suggestions from the study of dairy fungi. Jour. Myc. **11**: 117–124. (1905).

small, white patch on the surface. In two or three days, sporophores are thrown up from the prostrate mycelium. These bear branching hyphae which form terminally by abstriction, simple, continuous chains of conidia. This portion of the colony is usually gray to blue green in color, varying with the medium. The filaments of the mycelium in rich agar media often bear swollen cells, resembling chlamydospores in shape (pl. 11, f. 2), but which have not been observed to form the thicker wall, characteristic of such spores. Under the same condition, the mycelium becomes fluffy, and many filaments unite together in strands, forming *Coremium* clusters. The filaments ordinarily measure 3μ to 4μ in diameter, and contain elongated cells. On the other hand, the swollen cells are spherical, with a diameter of 4μ to 8μ.

Upon older cultures, especially upon wood, there are formed rounded tufts or clumps of curled and distorted hyphae and filaments, which are either lemon-yellow or orange-red in color, varying with the acidity or alkalinity of the culture medium. The color is due to the secretion of a pigment in the form of granules on the surface of the filament, evidently by exudation (pl. 11, f. 3). This pigment is readily soluble in slightly acid or alkaline water, in hot alcohol, and in some other solvents. It is red when alkaline and yellow when acid. The fungus, as a rule, when grown artificially, overcomes a moderate amount of alkalinity by the formation of an acid, and as a result, most cultures assume the lemon-yellow color when old. In cultures on wood, especially sapwood, the pigment is carried into the wood cavities by absorption, thus staining the wood. The color, although bright at first, fades as the culture grows old and dries out.

Conidia.

The conidia are borne on conidiophores which vary in length from 100μ to 500μ, with a diameter of 3μ, or slight-

ly more. These bear terminally a whorl of branched hyphae. The hyphal branches of either the first or second series average 12μ by 2μ. The conidial cluster is loose, and spreads out widely, averaging 100μ to 350μ by 35μ to 70μ (pl. 11, f. 1). The conidia are pointed oval in shape, varying from 3μ to 4μ in length, by 1.5μ to 2μ in diameter They are borne in simple chains of 40 to 80. They have a blue-green color, and contain a pigment soluble in hot alcohol, which does not change its blue-green color either by the addition of an acid or alkali.

Penicillium roseum Link.

A species of *Penicillium* which resembles *Penicillium roseum* Link was first found mingled with *P. aureum*. This fungus secretes a crimson red pigment which discolors sapwood. The work of investigation is not completed, and it is thought best not to give further details concerning this fungus at present. A third species has not been identified.

2. Fusarium.

The species of *Fusarium*, identified as *Fusarium roseum* Link, was isolated from pink, red and violet blotches found on new pine lumber taken from lumber piles near Ashland, Wis., in 1905. This grew readily under artificial culture, and upon inoculation was found to be the cause of the blotches upon the lumber. The boards from which the original cultures were taken were sawn from trees of *Pinus Strobus* L., and *P. resinosa* Ait. Similar stains have been found on pine boards from the southern United States made from *Pinus palustris* Mill., and *Pinus echinata* Mill., also on pieces of wood from *Pinus Virginiana* Mill.

This fungus, like other species of *Fusarium* that have been studied, varies in form, color, and habit of growth, depending upon the substratum upon which it grows. The

fruiting bodies are usually borne at or above the surface of the medium upon which it is cultivated. The following is a résumé of the cultural characters of the fungus:—

Mycelium.

The spores of the fungus germinate in a very short time, usually a few hours, and in thirty-six hours small white colonies are visible upon the surface of agar media. The first mycelium that forms is rather sparse, but thickens as the colony grows older. Two types of conidia are borne on the fertile hyphae, which are formed in a short time after germination of the spores. These are the microconidia (pl. 12, f. 1, 2, 3), which are found very numerously in all parts of the mycelium, except in the newest growth, and the macroconidia (pl. 12, f. 4, 5), which are found sparsely only in the older portions of the mycelium. Chlamydospores are formed abundantly in all the older portions of the colony about the time the growth of the mycellum is checked by a limitation of nutrition, being formed usually with or a little later than the macroconidia. The anastomosing of filaments is quite frequent (pl. 12, f. 8).

Microconidia.

Microconidia are formed in great numbers on various vegetable media, such as agar media made with plant decoctions. They are usually borne on hyphae which branch alternately from the mycelium. They are formed by the abstriction of the ends of hyphae, and where they are not disturbed by air currents or some sudden shock, they adhere to each other side by side in clusters which assume a form of fruiting resembling *Cephalosporium* (pl. 12, f. 3). These microconidia are at first one-celled. A septum is often formed before the spore becomes detached from the hypha, and later many of the one-celled conidia that have fallen off form septa. The two-celled form

slightly resembles the conidia of *Cephalothecium* (pl. 12, f. 3).

The microconidia are oval to elliptical in shape, varying in length from 8μ to 14.5μ, and in diameter from 3μ to 6μ. They are hyaline, colorless, thin walled, and are usually uninucleate. Many are slightly curved.

Macroconidia.

The macroconidia are of the *Fusarium* type, and vary considerably in shape and size. They are usually formed by abstriction of the ends of short, swollen, branching hyphae, and are from two- to four-celled, straight or curved, with tapering, rather blunt ends, varying in length from 19μ to 30μ, and in diameter from 3.5μ to 6μ. Both microconidia and macroconidia germinate readily on all ordinary agar culture media, the time varying with the medium. The macroconidia are rarely found attached to the hyphae when fully mature.

Chlamydospores.

Both terminal and intercalary chlamydospores are formed singly or several in series (pl. 12, f. 6, 8, 9). They are formed by the enlargement of the cells of the mycelial filaments. Their development is more gradual than that of the conidia, and the cell wall is much thicker. In shape they are spherical, or slightly oval. The cell contents are granular, and vary in color from yellow to dark brown. The diameter of the spores averages 12μ. When the macroconidia start to germinate, and are hindered by a sudden drying out, or other adverse conditions, it is not unusual for one of the cells to form a chlamydospore (pl. 12, f. 5); these are rarely mature, and have never been observed to germinate.

Sclerotia.

Sclerotia are produced in cultures on boiled potato and

rice. They vary in color from dark green to dark brown. As they grow older they become rather hard and dense, but bear no definite fruiting bodies.

Perithecia.

In all of our cultures no perfect form of fruiting has been found, although the fungus has been grown on all the common culture media. If such form exists, our failure to find it is due to the fact that natural conditions were not imitated closely enough to produce it.

The Formation of Color.

On pine sapwood, a red or purple color is produced, which in old cultures fades to a dirty brown. A number of species of *Fusarium* are now being grown on pine wood for comparison with this, and the results will be published at a later date. *Fusarium roseum* secretes a soluble pigment which is taken up by the adjacent wood cells, staining them lightly with a red or purple color, which varies with the acidity or alkalinity of the wood. In natural wood, which is slightly acid, the color varies from a pink to a lilac. In cultures where there is a profuse growth of the mycelium the colored chlamydospores and mycelium modify the appearance of the wood, giving it a dull color in contrast with the original brighter one.

CAUSES OF COLOR IN WOOD STAINED BY THE FUNGI INVESTIGATED.

1. Ceratostomella.

The cause of the blue-gray or blue-black stain in wood penetrated by the mycelium of *Ceratostomella* lies in the color of the filaments of the fungus, which exudes no stain from its mycelium. The dark brown pigment in the walls

of the filaments is insoluble in alcohol, ether, chloroform, benzol, alkalis and acids. The brown color of the fungus apparently contains traces of a blue pigment whose color is transmitted by the wood cells of pine more readily than the brown color.

2. Graphium.

The mycelium of *Graphium* imparts a dingy gray or brown, or even a black color to the wood it enters. This is caused by the color of the mycelium, and is due to no soluble pigment. The cells of the wood remain unstained.

3. Hormodendron and Hormiscium.

The cells of wood penetrated by these wood-blackeners are not stained, the color being due to the presence of the mycelium of the fungi. It is not yet known whether the color is one that may be extracted.

4. Penicillium.

The species of *Penicillium* discoloring wood form a soluble red or yellow pigment which is taken up by the cell walls of the wood, giving them a red or yellow stain which fades when the wood dries out, but is increased in intensity when it is moistened again.

5. Fusarium.

The wood stained by *Fusarium* is discolored both by a soluble pigment which is secreted by the fungus and taken up by the wood cells and by the presence of colored hyphae and chlamydospores.

The investigation of color production by these fungi will be carried on in the future, and it is hoped that the nature and composition of some of these pigments may be discovered, and that other facts may be found worthy of publication.

KEY TO THE SPECIES OF FUNGI DESCRIBED IN THIS PAPER.

A. Colonies at first white, changing color later. First fruiting stages, clusters of hyaline conidia borne on upright hyphae which usually collect together in rounded masses under moist conditions.

a. Staining wood bluish, black or brown; with beaked perithecia. CERATOSTOMELLA.

1. Conidia borne in short, branching moniliform chains on upright hyphae.

* Beaked ostiolum more than twice the height of the perithecium.

† Fringe to ostiolum terminal.

§ Terminal filaments short and often thickened.

Perithecium smooth or sparsely hirsute. *C. pilifera.*

Perithecium often with outgrowths. *C. Schrenkiana.*

Perithecium with glandular hairs. *C. echinella.*

§§ Terminal filaments long and slender. *C. capillifera.*

‡ Fringe to ostiolum often supplemented by additional rings beneath. *C. pluriannulata.*

** Beaked ostiolum only once or twice the height of the perithecium.

Terminal filaments short and thickened. *C. minor.*

Terminal filaments lengthened and slender. *C. exigua.*

2. Conidia borne continuously, either singly or in moniliform chains. Perithecium with conical spines. *C. moniliformis.*

b. Staining wood gray to brown or black; mycelium bearing stromata or stalked heads. GRAPHIUM.

1. Secondary conidia resembling those of *Sporotrichum.*

Stroma finally brown to black, heads white to brown. *G. ambrosiigerum.*

Stroma finally brown or olive, heads greenish. *G. eumorphum.*

Stroma finally dark green to black, heads gray. *G. atrovirens.*

2. Secondary conidia differing from those of *Sporotrichum.*

* Conidia formed continuously, falling together as rapidly as formed.

Stroma finally dark green to black, heads white to gray or green. *G. smaragdinum.*

Stroma finally gray to black, heads white to creamy yellow. *G. rigidum.*

** Conidia in simple whorls or in whorls of branching moniliform chains.

Stroma finally yellow to brown, heads yellow to light brown. *G. aureum.*

Stroma finally brown to olive, heads white to yellow. *G. album.*

B. Colonies at first gray, later brown or black, conidia dark colored, borne in branched chains in clusters from upright hyphae.

HORMODENDRON.

Velvety colonies, yellow-green at first, then olive to black.

H. cladosporioides.

Furry colonies, light to dark gray, finally almost black. *H. griseum.*

C. Colonies yeast-like at first, mucilaginous, finally turning brown or black. HORMISCIUM.

Mycelium cream-colored, then brown, conidia dimorphous, chlamy. dospores present. *H. gelatinosum.*

D. Colonies gray, green, yellow or red, conidia hyaline or slightly colored, borne in clusters of simple chains from branched upright hyphae. PENICILLIUM.

Mycelium dimorphous, lemon-yellow to orange in one form, gray or blue-green in the other; staining wood yellow or red. *P. aureum.*

Mycelium white or pink to red; staining wood crimson.

P. roseum (?)

E. Colonies white, often changing to red or lilac, microconidia one- to two-celled, macroconidia several celled, fusiform or sickle-shaped.

FUSARIUM.

Staining wood pink, red, or purple, or even brown in old cultures.

F. roseum.

EXPLANATION OF PLATES.

The illustrations are from camera lucida drawings by the author except for pl. 6, f. 7, 8, drawn by Miss Laura L. Eames. Throughout, perithecia and their tips, and stromata, are enlarged 50 diameters; and mycelial structures, conidiophores, conidia, and ascospores are enlarged 500 diameters.

Plate 3. — Ostiola of *Ceratostomella.* 1. *C. capillifera.* 2. *C. exigua.* 3. *C. echinella.* 4. *C. minor.* 5. *C. moniliformis.* 6. *C. Schrenkiana.* 7. *C. pluriannulata.* 8. *C. pilifera.*

Plate 4. — *Ceratostomella Schrenkiana.* 1, 2. Conidial clusters. 3. Ascospores. 4. Young perithecium, with conidiophores from some of the older hyphae. — *C. pilifera.* 5, 6. Conidial clusters. 7. Germinating conidia. — *Cephalosporium*-like aggregations are shown in figures 1, 5, and 6.

Plate 5. — *Ceratostomella pluriannulata.* 1. A conidial cluster. 2. An ascus and ascospores. — *C. moniliformis.* 3. Conidial clusters. 4. A moniliform chain of conidia formed like arthrospores, two conidia germinating. 5. *A. Cephalosporium*-like aggregation of conidia termi-

nating two moniliform chains. — *C. minor.* 6. Perithecium almost mature. 7. An ascus and ascospores.

Plate 6. — *Ceratostomella echinella.* 1. A conidial cluster. — *C. capillifera.* 2. A conidial cluster. 3. *Cephalosporium*-like aggregations of conidia. — *C. exigua.* 4, 5. Conidial clusters, one having become massed. 6. Conidia. 7. Ascospores.

Plate 7. — *Graphium eumorphum.* 1. Stroma with heads. 2. Clusters of secondary conidia. 3. Secondary conidia. 4. Parallel hyphae composing a portion of a stromatic stalk. 5. Branches of hyphae bearing primary conidia from head. — *Graphium rigidum.* 6. Stroma with head. 7. Conidial masses on surface of an agar culture, secondary conidia. 9. Primary conidia. 10. Germination of primary conidia.

Plate 8. — *Graphium atrovirens.* 1. Stromata with heads. 2. Clusters of secondary conidia. 3. Compound cluster, or side clusters of secondary conidia. — *Graphium ambrosiigerum.* 4. Stroma with heads. 5. A cluster of secondary conidia. 6. Stroma, origin of stalk bearing head. 7. Filament bearing primary conidia from head.

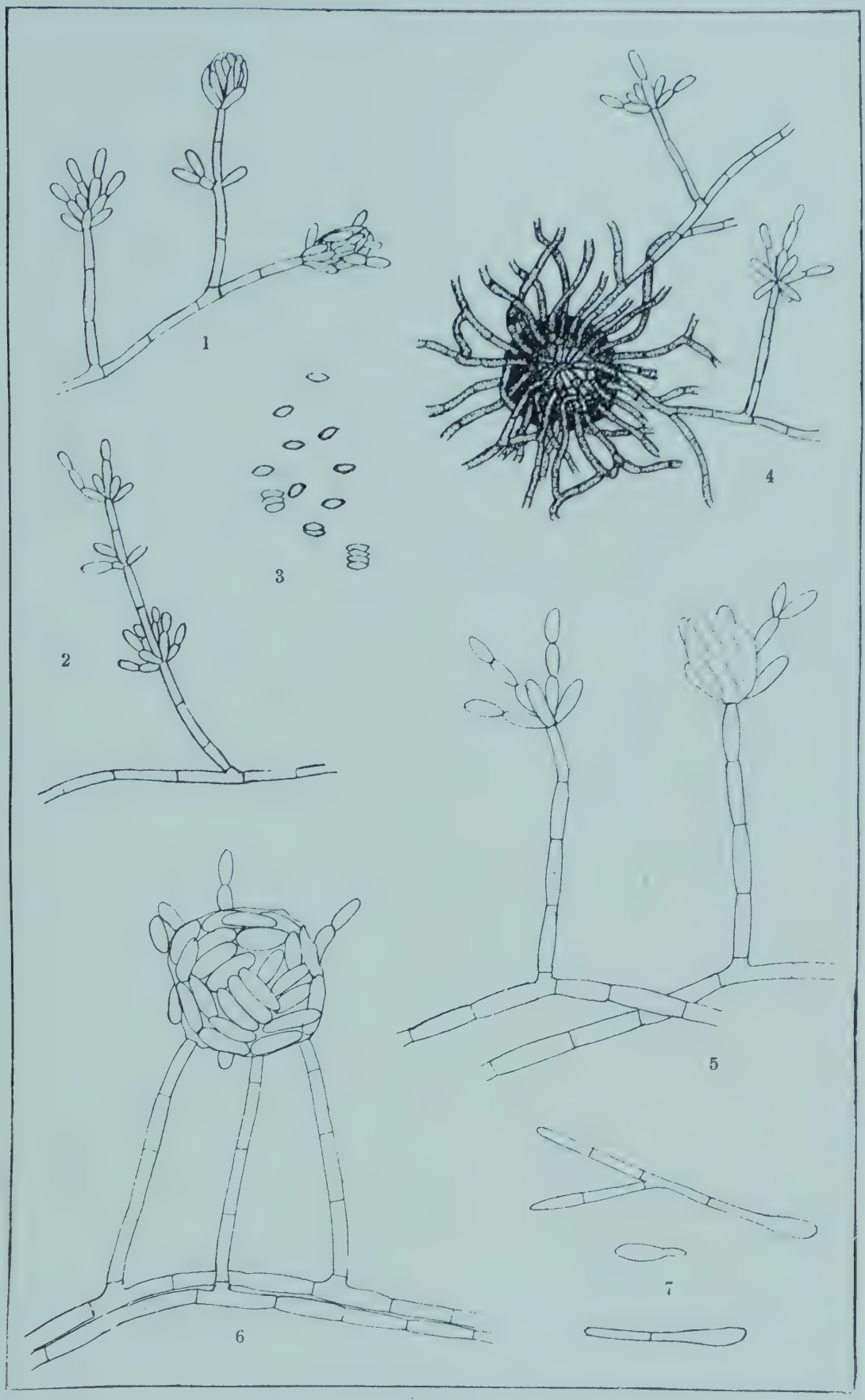
Plate 9. — *Graphium album.* 1. Stromata with heads. 2. Clusters of secondary conidia. 3. Compound cluster of secondary conidia. 4. Primary conidia.— *Graphium aureum.* 5. Stromata with heads. 6. Conidial clusters and masses of secondary conidia. 7. Primary conidia. — *Graphium smaragdinum.* 8. Stromata with heads. 9. Clusters of secondary conidia. 10. Filaments bearing primary conidia from head.

Plate 10. — *Hormodendron cladosporioides.* 1. Conidial clusters. — *H. griseum.* 2. Conidial clusters, the smaller showing a *Cladosporium* type.

Plate 11. — *Penicillium aureum.* 1. A portion of a conidial cluster with two complete chains of conidia, the remainder being incomplete and the conidiophore drawn in two pieces. 2. A portion of the mycelium from a culture of pine-decoction agar showing swollen cells suggestive of chlamydospore formation. 3. A filament rugose with a deposit of a colored granular exudation. — *Hormiscium gelatinosum.* 4. A colony on agar showing the toruloid form, (enlarged 6 times). 5. A hypha with hyaline yeast-like conidia. 6. Brown form of loosely attached conidia. 7, 8. Conidia in chains borne on short hyphae, the *Hormiscium* type.

Plate 12. — *Fusarium roseum.* 1, 2. Microconidia, *Verticillium*-like forms. 3. Microconidia aggregated in *Cephalosporium*-like masses and at the same time becoming uniseptate. 4. Microconidia one- to two-celled, macroconidia three- to four-celled. 5. Formation of abortive chlamydospores caused by the arrested germination of macroconidia. 6, 7, 8. Chlamydospore formation.

CERATOSTOMELLA.



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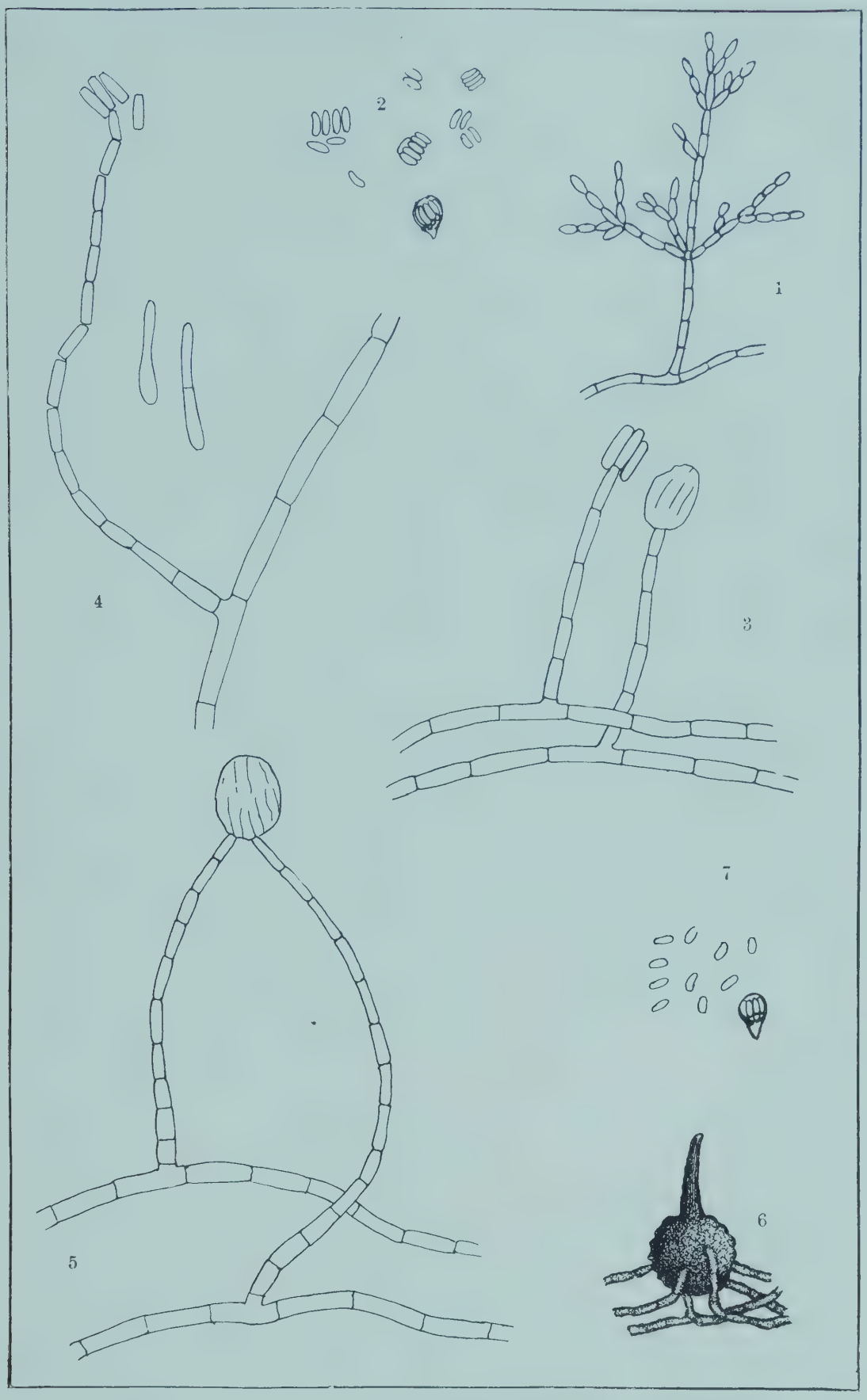

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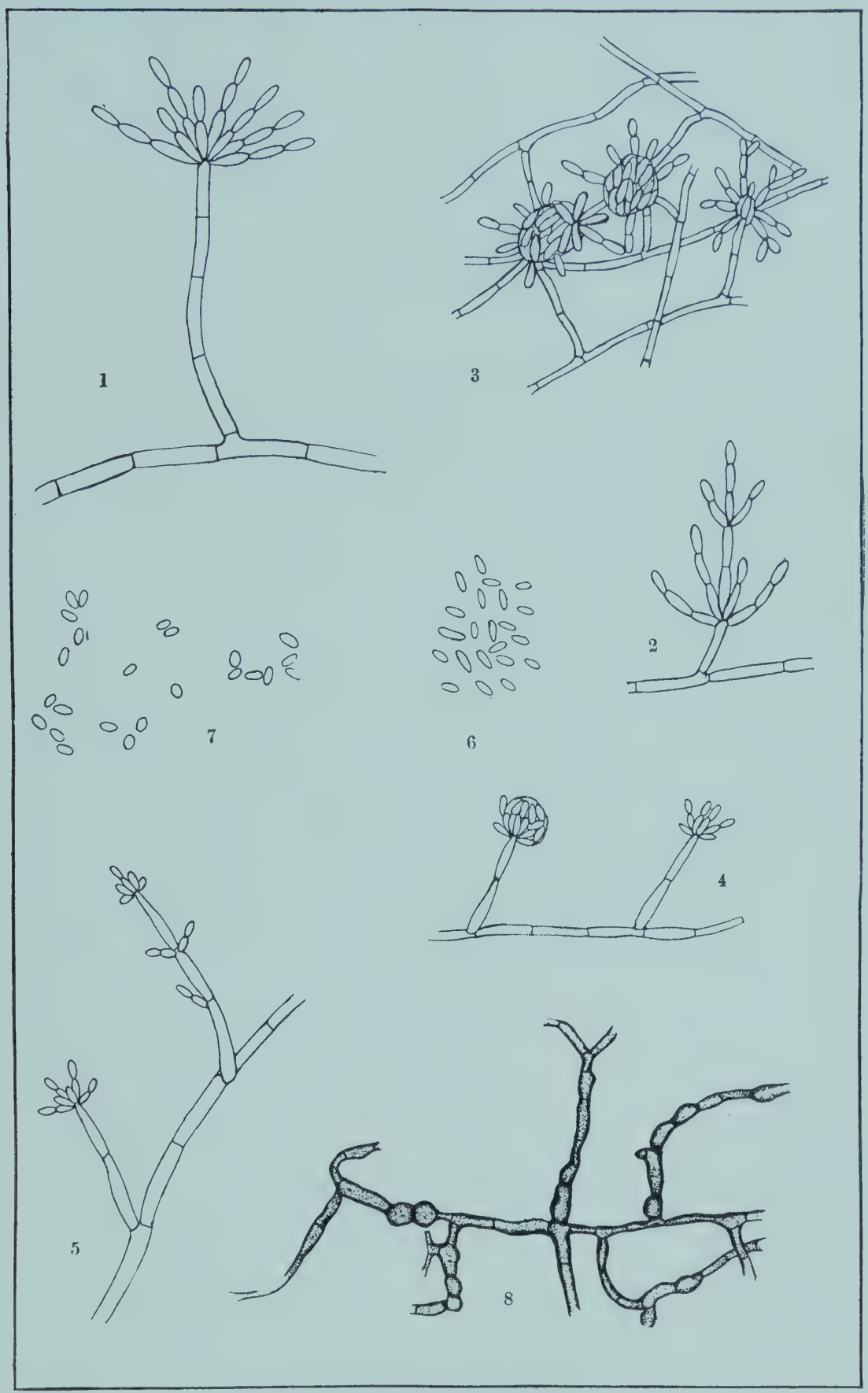

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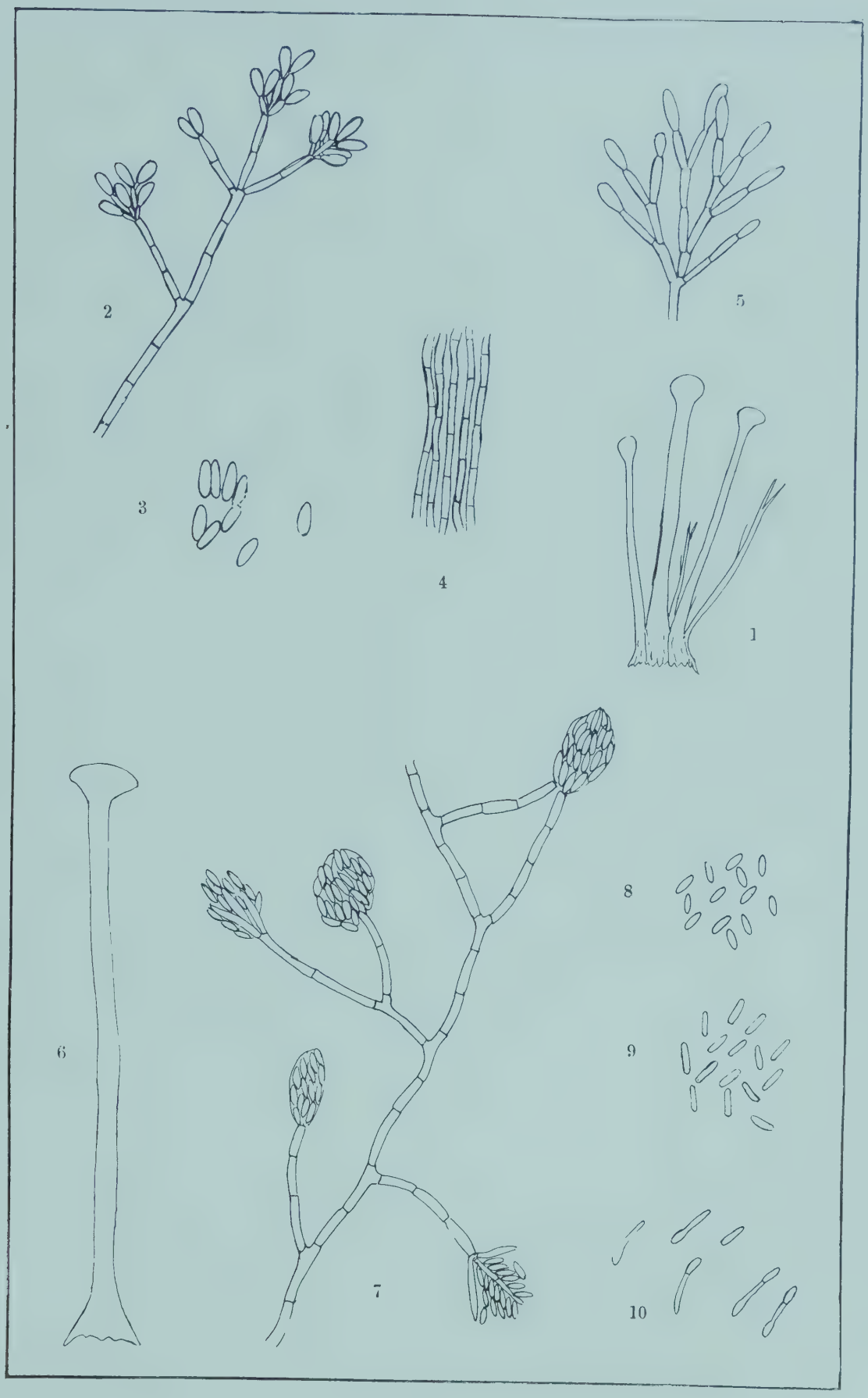
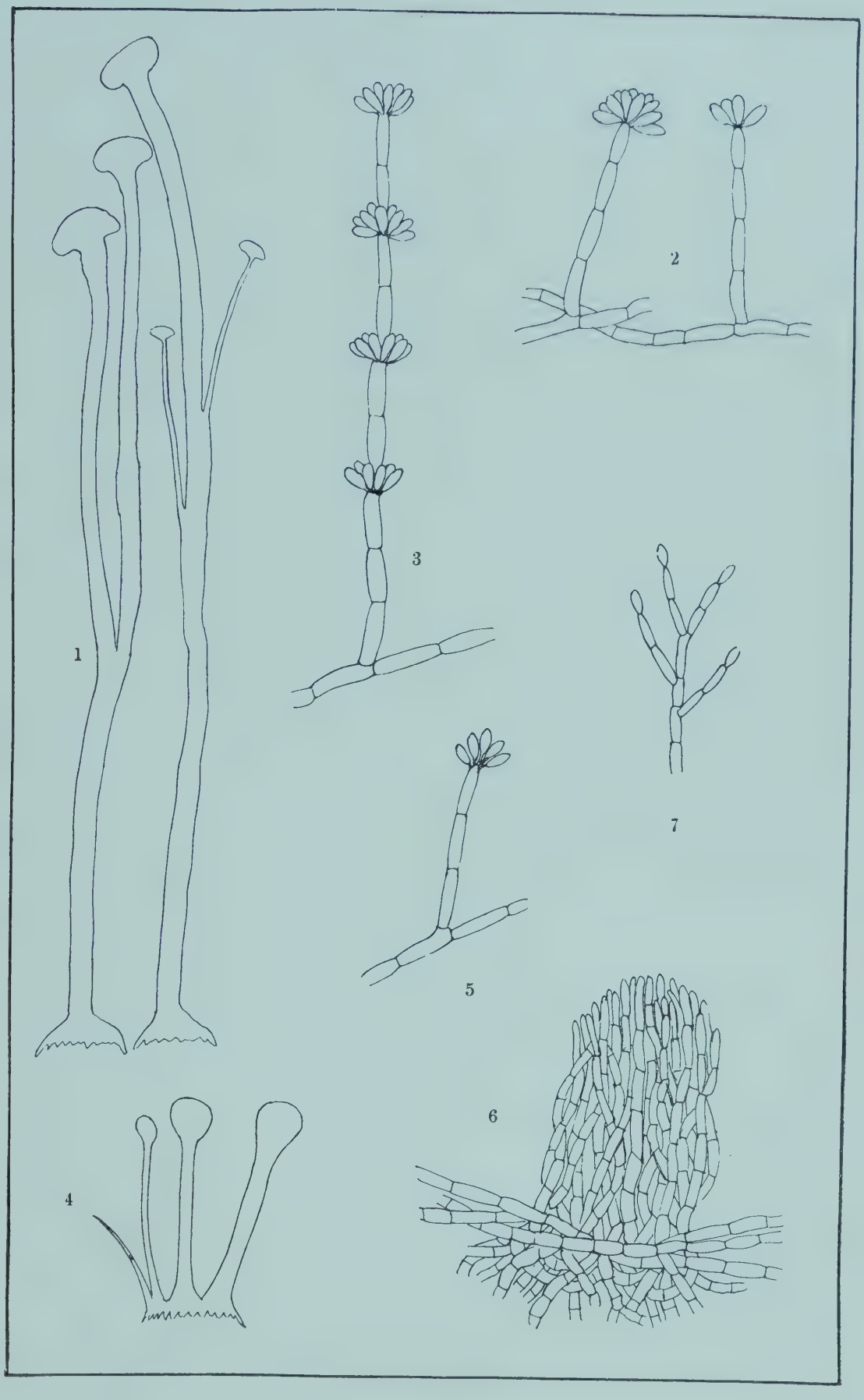


GRAPHIUM.



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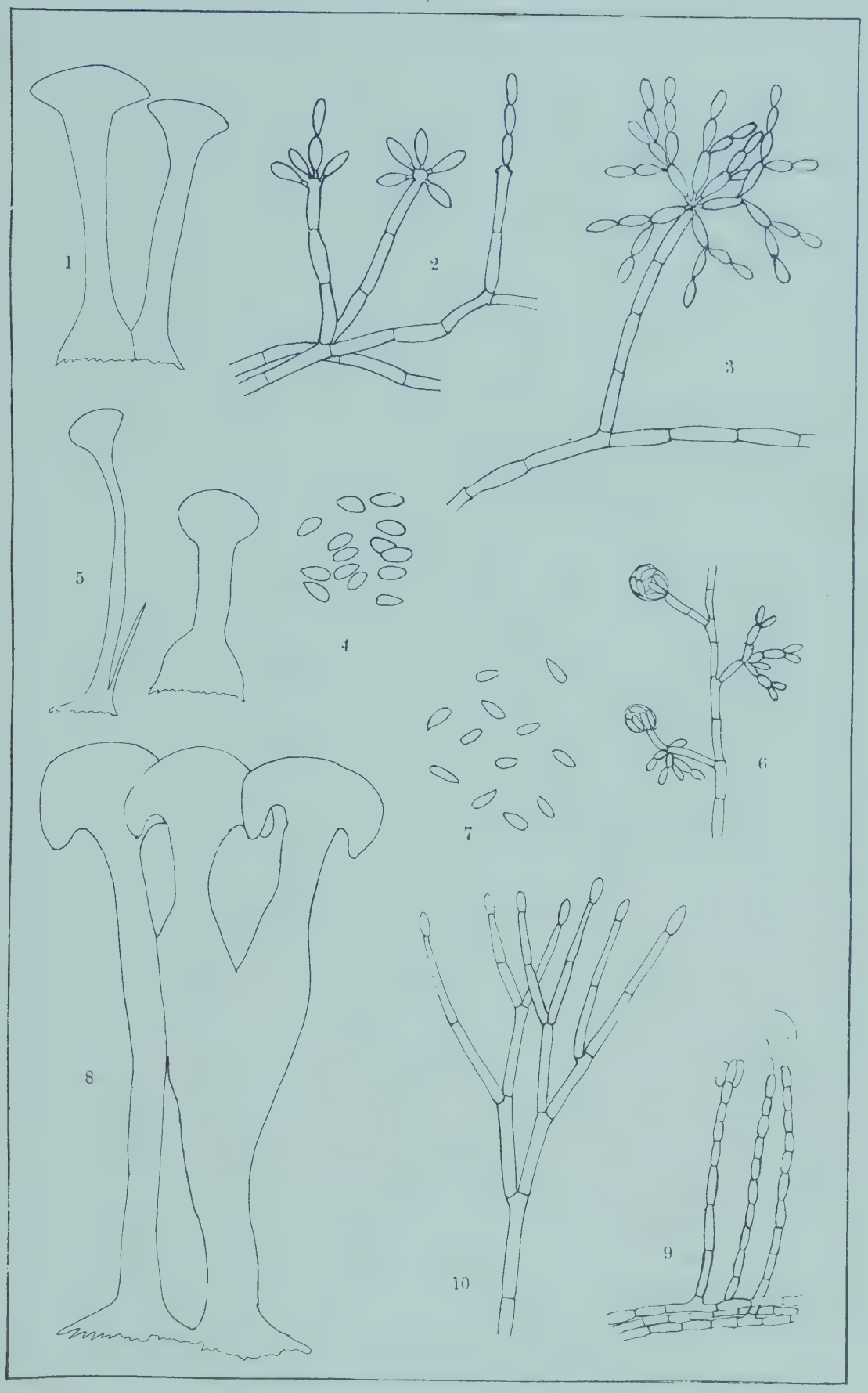

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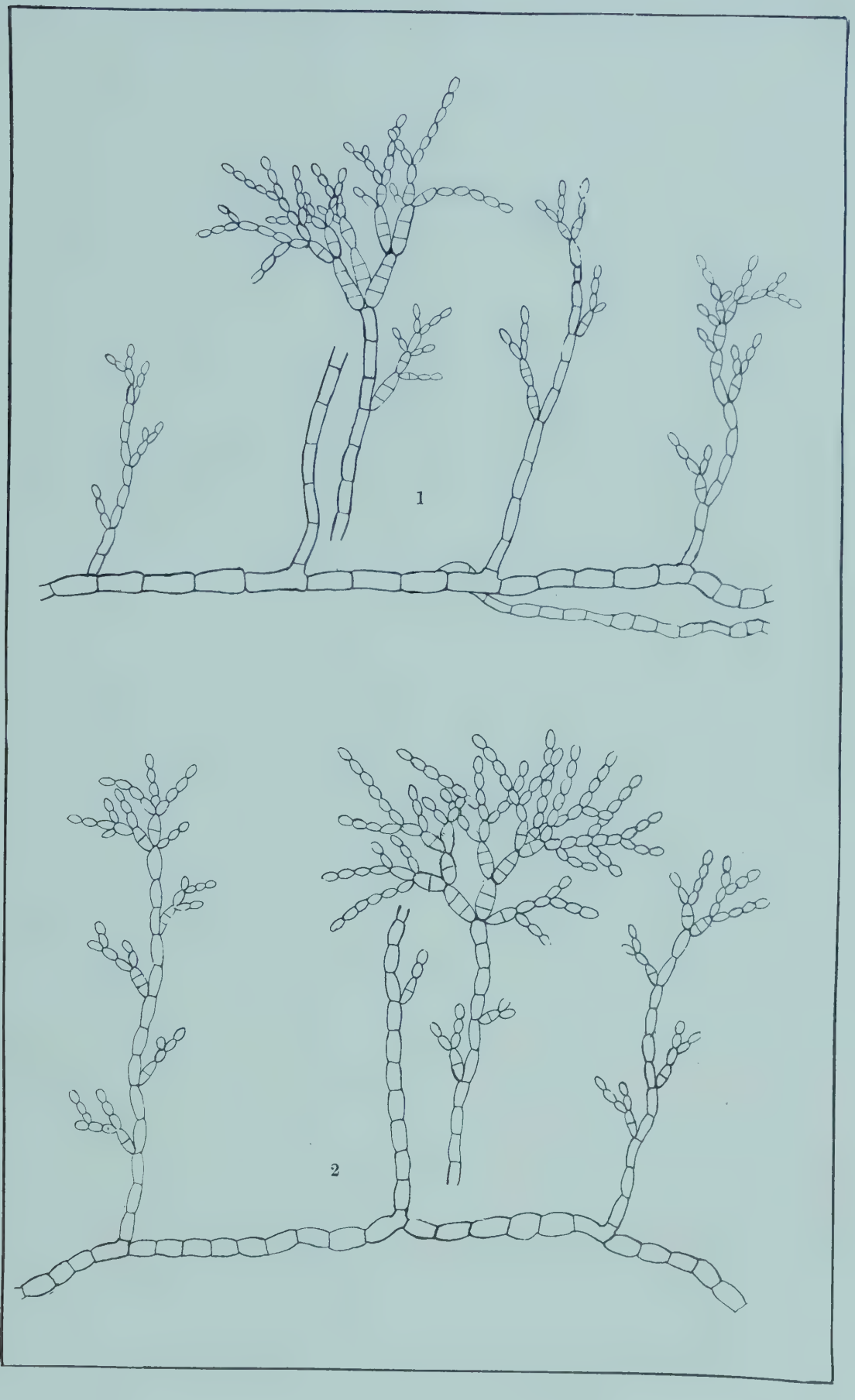
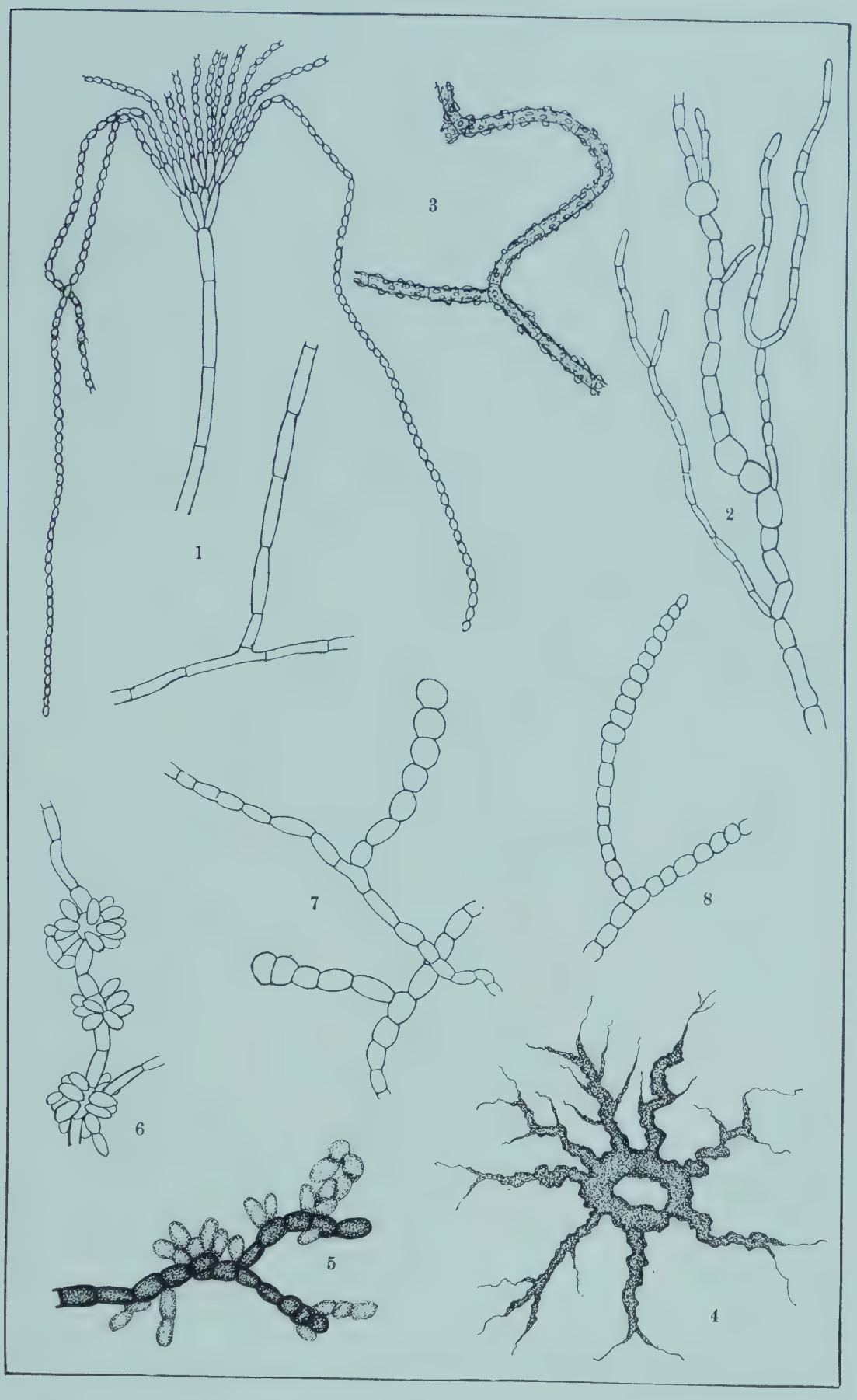
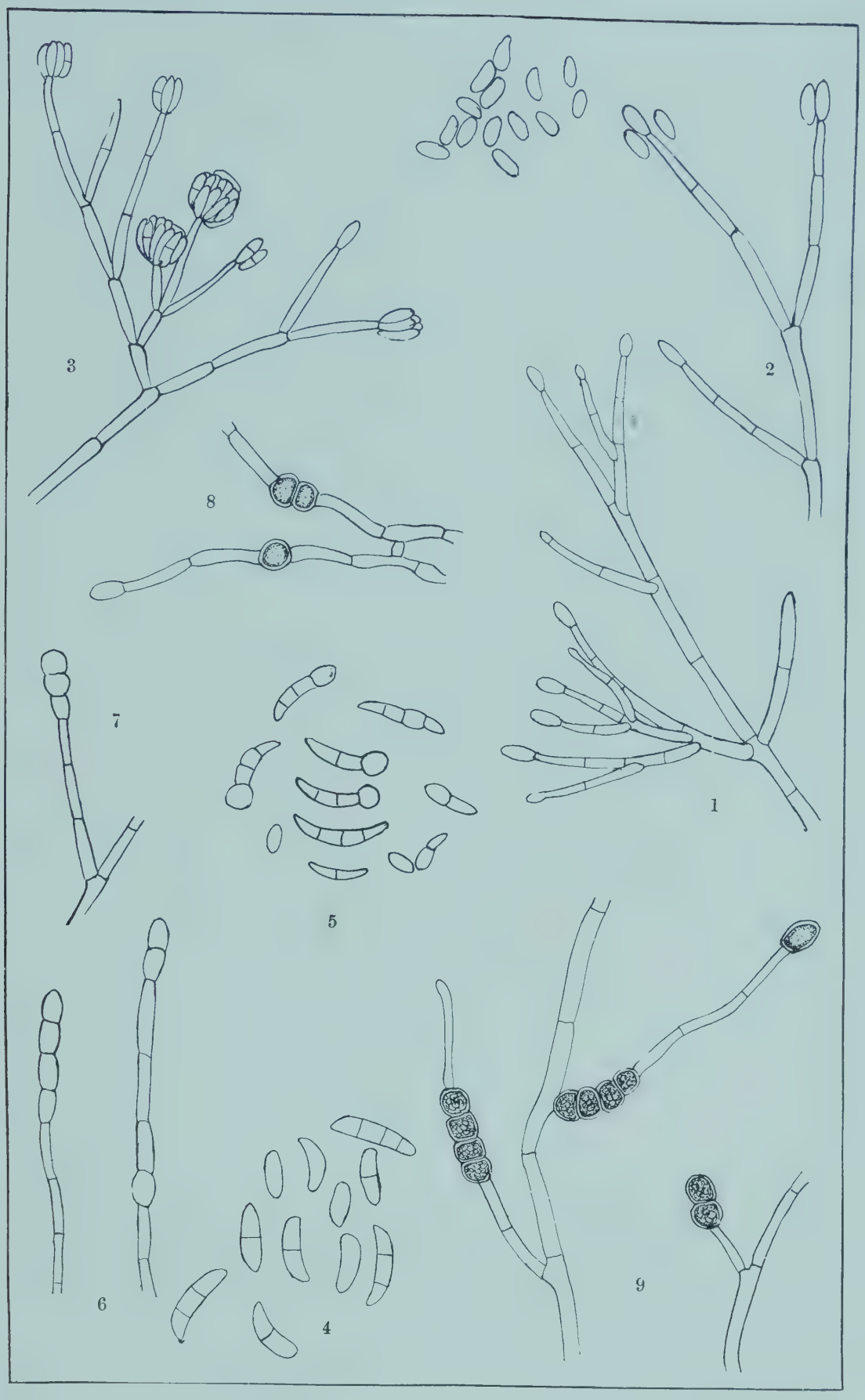


HORMODENDRON.



PENICILLIUM AND HORMISCIUM.



FUSARIUM ROSEUM.

ZONATION IN ARTIFICIAL CULTURES OF CEPHALOTHECIUM AND OTHER FUNGI.

BY GEORGE GRANT HEDGCOCK.

The results given in this paper are from a continuation of the investigation, mention of which was made in a brief paper to the American Mycological Society at the Philadelphia meeting, December, 1904, and are published by permission of the Secretary of Agriculture.

Certain fungi like *Cephalothecium*, *Penicillium*, *Mucor* etc., often exhibit in artificial cultures a distinct zonation of the mycelium due to denser masses of spores being formed daily on certain portions of the mycelium, often giving an agar plate culture the ringed appearance of a target. Last year it was proven by a set of experiments that daily variations of temperature are not the cause of this zonation. At the same time it was shown that they were not produced under conditions of total darkness, but occurred only in cultures grown in the light.

In order to determine what colors of light affect spore formation, cultures of *Cephalothecium*, *Penicillium*, *Mucor*, and *Hormodendron* were grown on agar plates under five conditions of light. Double bell jars of ordinary glass were filled with solutions as follows: for orange light, potassium bichromate; for red, a cochineal solution; for blue, a mixture of ammonium and copper carbonate; for green, a mixture of "anilin gelb" and "licht grün;" for ordinary light, a double bell jar without a solution; and for darkness, a tight, black-lined box. No spectrum analysis of the rays of light transmitted by some of these solutions has yet been made.

The cultures grown under red and orange light, and in darkness, exhibited a uniform dense spore formation over the whole surface of the mycelium in every instance.

The cultures grown under blue light and in ordinary light, in every instance exhibited distinct daily rings of

growth of alternating denser spore formation of a texture similar to that of the former set of cultures; but between the denser concentric rings were regions where spores were only sparsely formed.

Cultures under green light exhibited rings of growth of less distinctness, indicating that it is the blue rays of light that affect spore formation. Careful observation established that the rings of sparse spore formation are formed in the daytime, and the denser at night, proving that the blue rays of light inhibit spore formation in these fungi.

Cultures of *Cephalothecium* taken from decaying sugar beet roots and from rotting apples were much more sensitive to blue light than the same fungus taken from the fruits of *Rosa rugosa*. The species from all these sources was one and the same, if mycological characters were to decide the question; yet, the difference in growth on various media under blue light suggests that we have two distinct physiological forms of *Cephalothecium roseum*. The form occurring on apples and sugar beets grows more often in the dark in nature, in stored apples and beets; the one on the fruits of the rose is found growing on the rose fruits in open light. May it not be that the latter has become more accustomed to strong light, and is less affected by the blue rays?

There is another type of zonation in artificial cultures of some fungi which is not due to light stimuli, but probably to variations in the amount of food taken in by the mycelium, and to possible resting periods in spore formation. This type has been observed by the writer in a number of species of fungi; among these is *Hypocrea*. Thomas Milburn mentions this type of ring formation in his studies of *Hypocrea rufa* and other fungi.* In *Hypocrea* the concentric rings are formed, not daily, but in a much longer period of time.

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* See Centralbl. für Bakt. Par. u. Infek. **13**: 129–138.

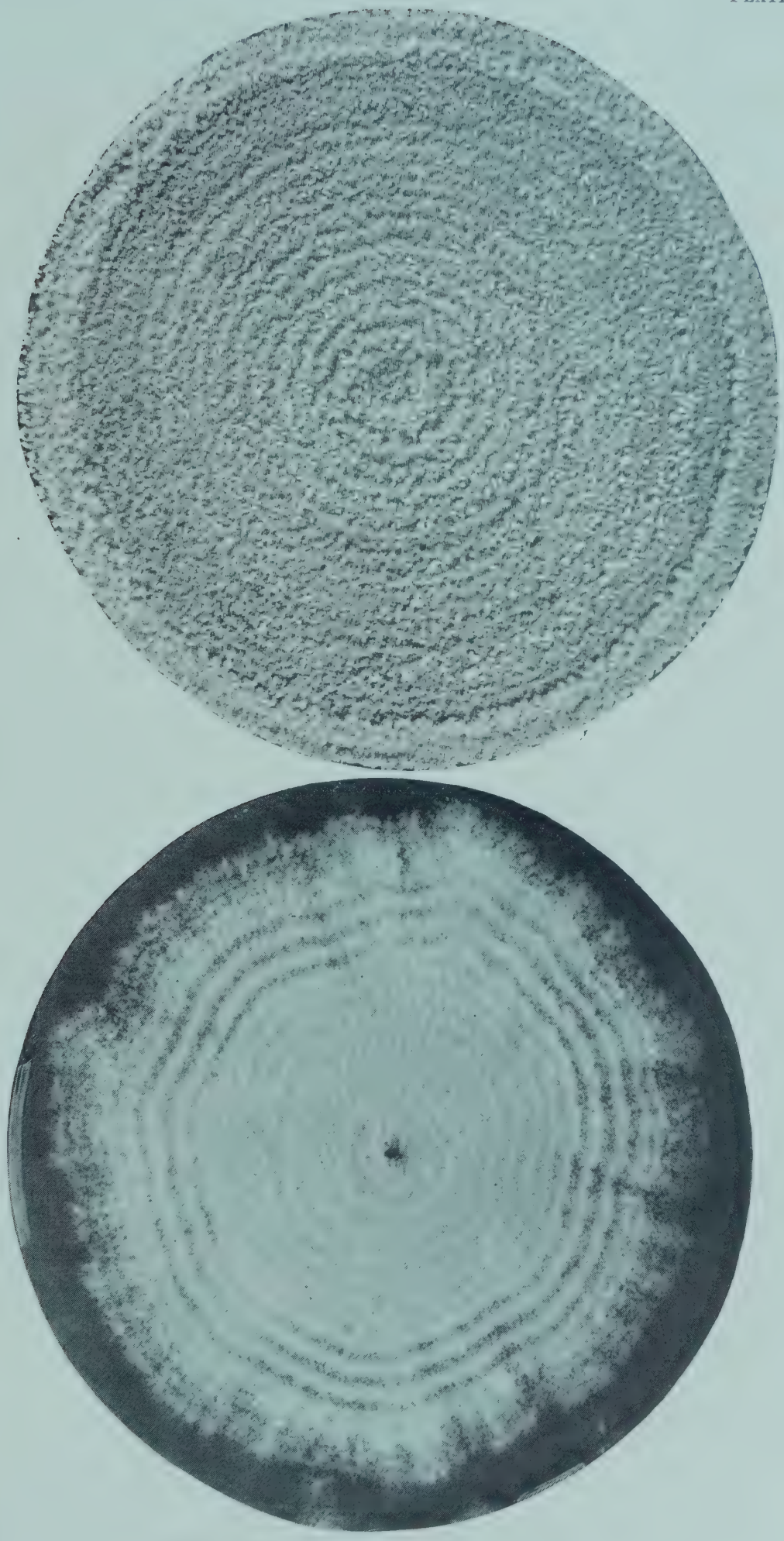
EXPLANATION OF PLATES.

Plate 13. — 1. *Penicillium album*, grown in the light. 2. *Cephalothecium roseum* from sugar beet roots, grown in light. — Natural size.

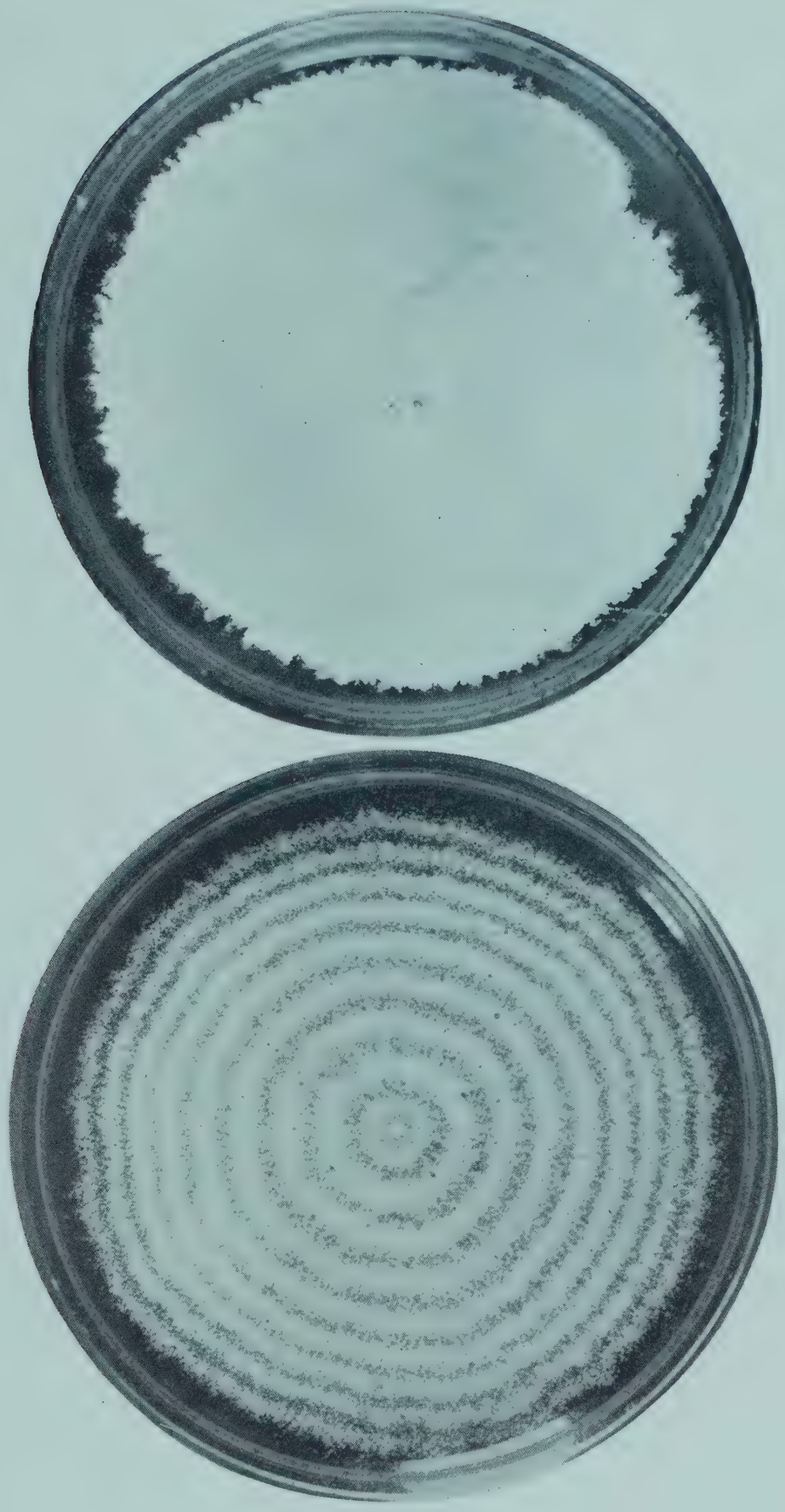
Plate 14. — 1. *Cephalothecium roseum*, from apple, grown in darkness. 2. Same, grown in light.

Plate 15. — 1. *Cephalothecium roseum*, from *Rosa rugosa* fruits, grown in darkness. 2. Same, grown in orange light. — Colonies enlarged.

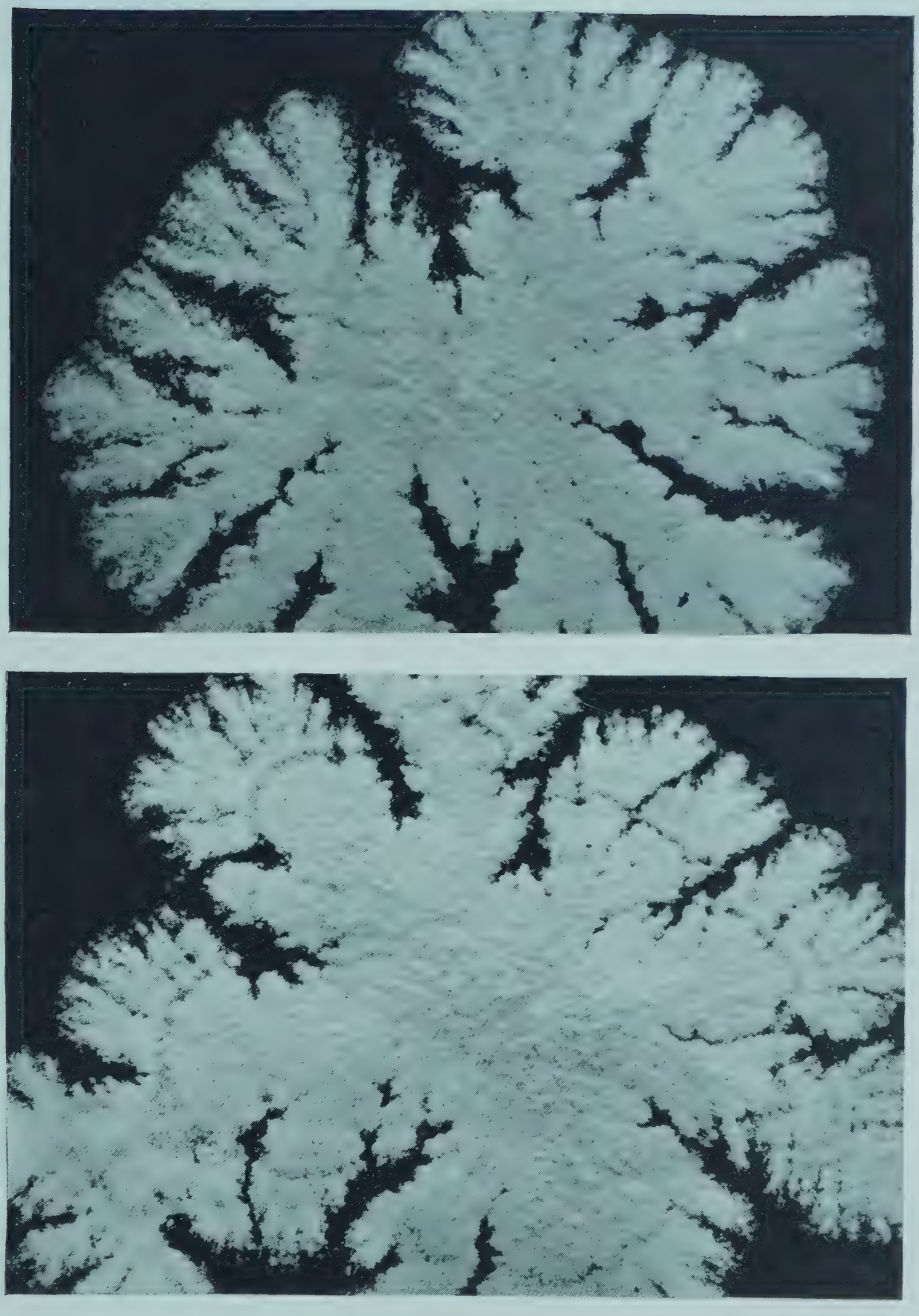
Plate 16. — 1. *Cephalothecium roseum*, from *Rosa*, grown in blue light. 2. Same, grown in natural light. — Colonies enlarged.



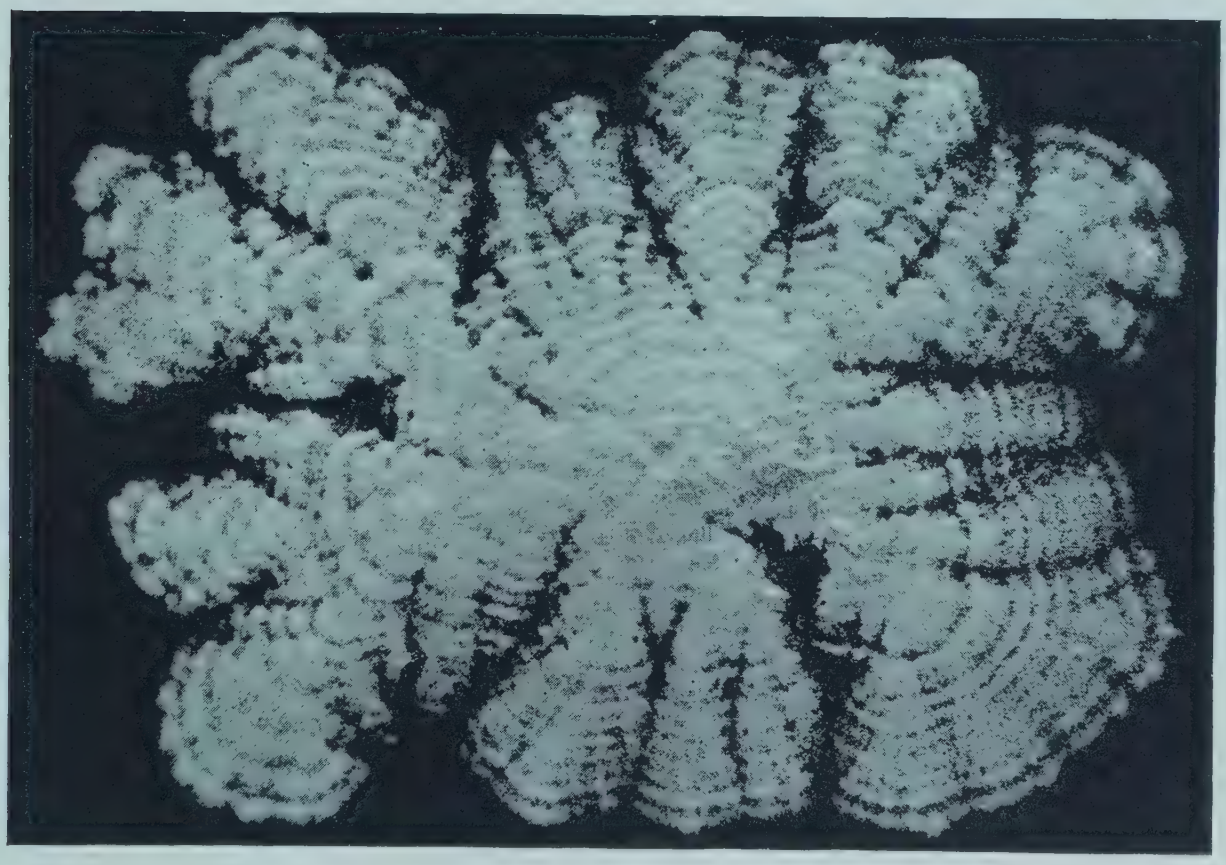
PENICILLIUM AND CEPHALOTHECIUM.



CEPHALOTHECIUM ROSEUM.



CEPHALOTHECIUM ROSEUM.



CEPHALOTHECIUM ROSEUM.

SOME NEW TEXAS PLANTS.

BY B. F. BUSH.

TRACYANTHUS ANGUSTIFOLIUS TEXANUS n. var.

Foliage glaucous. Stems 7–15 dm. tall, simple, with compound racemes at the top. Leaf-blades narrowly linear, 2–6 dm. long, shorter above, flat; racemes ovate in outline, compound, 10–20 cm. long; pedicels slender, 1–2 cm. long; perianth decidedly yellowish; sepals and petals oblong, narrowed at the base, the sepals somewhat broader, all 4–5 mm. long, acutish at the apex; capsules not seen.

Sandy swamps, eastern Texas. Spring.

Differs very greatly in appearance from *T. angustifolius* (Michx.) Small, in the large compound panicles, the more robust size, and in the decidedly yellowish flowers.

Specimens examined: TEXAS: The only specimens seen are those of the type, collected at Swan, Smith County, by *J. Reverchon* 2782, May 16, 1902.

ALLIUM HYACINTHOIDES n. sp.

Bulbs usually several together in bunches, 2–3 cm. high, their coats prominently fibrous-reticulated. Scapes terete, 2–3 dm. tall; leaves basal, channeled, 3–4.5 mm. wide, much shorter than the scape; bracts of the umbel 3, ovate, acuminate; umbel erect, many-flowered, rarely bulblet-bearing; pedicels filiform, 12–15 mm. long; flowers pink, very sweet-scented, 6–9 mm. long; perianth segments oblong, obtuse, thin, with a reddish midvein, twice longer than the stamens; filaments but little dilated below; capsule 3–3.5 mm. high, 4–4.5 mm. wide, its valves not crested.

Calcareous limestone prairies, central Texas. Early spring.

A. hyacinthoides is quite readily distinguished in the field by its very fragrant attractive pink flowers, very early blooming, and habit of growing in bunches. From *A. mutabile* Michx., to which it is related, and with which it has been confused, it differs in being very fragrant, in having shorter stems, rather longer obtuse sepals which are twice longer than the stamens, smaller capsules, shorter pedicels, different habitat, and an earlier season of blooming. *A. mutabile* Michx. grows in sandy woods about Dallas, Texas, and blooms from two to four weeks later.

Specimens examined: TEXAS: Dallas, *Bush* 270, April 14, 1900; *Reverchon* 2183, April 5, 1900; *Reverchon* 4025, April 1, 1880.

PSORALEA SUBULATA n. sp.

Acaulescent or nearly so, 1.5–3 dm. tall, from a shallow seated, oval, farinaceous bulb. Stems densely pubescent with long, shaggy white hairs, many-leaved and many-flowered. Petioles 1–2 dm. long, much stouter and longer than the peduncles, commonly considerably exceeding them and mostly from the base of the stem; leaflets 5, digitate, short-stalked, broadly obovate, with a cuneate base, obtuse and rounded at the apex, cuspidate-tipped, very pubescent beneath with long, shaggy white hairs, sparsely so above, 3.5–6 cm. long, and 2–2.75 cm. wide; peduncles from the base of the stem, 5–10 cm. long, commonly reclining or recurving; spikes many, oblong, dense, 5–8 cm. long, 2.5–4 cm. thick, very many flowered; bracts lanceolate, shorter than the calyx-tube, about 7.5 mm. or less long; calyx-teeth subulate, 6–10 mm. long; pod oblong, 4–5mm. long, nearly smooth, tipped with a long, densely hairy subulate beak, which is 12–15 mm. long.

Dry sandy soil along streams, eastern and central Texas. Summer.

P. subulata is allied perhaps more nearly to *P. hypogaea* Nutt., but is abundantly distinct from that species in the larger differently shaped leaflets, larger and longer spikes, and different habitat, *P. hypogaea* Nutt. growing on the rich prairies about Dallas. It is easily distinguished from *P. esculenta* Pursh, by its nearly acaulescent habit, differently shaped leaflets, larger and stouter petioles, different habitat, and the long subulate beak of the pod.

Specimens examined: TEXAS: Dallas County, *Bush* 697, May 10, 1900, type: Hempstead, *Hall* 1350, June 28, 1872.

PSORALEA PALUSTRIS n. sp.

Perennial from a deep elongated tuber. Stems 6–9 dm. tall, slender, erect, simple, unbranched, strigose-hirsute; stipules linear-subulate; leaflets 3, the blades lanceolate to narrowly oblong, strigose-hirsute, 4–7 cm. long, and 1–1.5 cm. wide, rugose-veiny, acutish; peduncles 5–10 cm. long, as long as or longer than the subtending leaves, equalling or exceeding the racemes in length; racemes 4–5 cm. long, not elongating in fruit; pedicels of the flowers 3–6 mm. long; tube of the calyx campanulate, thickly glandular-dotted; corolla 6–9 mm. long, deep purple; bracts linear-aristate; pods suborbicular, apiculate by the style, 4–5 mm. long, strongly transversely wrinkled, scarcely margined, thickly glandular-dotted.

Sandy swamps, eastern Texas. Summer.

This species differs from *P. pedunculata* (Muhl.) Vail, in the taller, unbranched stems, more strigose foliage, larger and longer leaves, longer pedicels of the flowers, lax racemes, shorter peduncles, and especially in the marshy habitat, and in the large deep purple flowers which are produced much later in the season, *P. pedunculata*

(Muhl.) Vail flowering more than a month earlier in the same locality.

Specimens examined: TEXAS: Lindale, *Reverchon* 3175, May 15, 1902, type; 3016, June 9, 1902; Big Sandy, *Reverchon* 2658, May 19, 1901.

TRAGIA NIGRICANS n. sp.

Perennial, bright green, smooth and glabrous, turning blackish in drying. Stem slender, erect, 2.5–4.5 cm. tall, simple or few-branched; leaves thickish, oblong or oblong-lanceolate, deeply dentate or laciniate, sometimes lobed, acute at the apex and base, short-petioled, or the uppermost sessile, glabrous beneath, sparingly pubescent on the midrib above, and copiously ciliate with long white hairs, 2.5–7.5 cm. long, and .5–2.5 cm. wide; flowers in lateral, short, spike-like racemes from the upper axils; staminate flowers with a 3-lobed calyx and 3 stamens; pistillate flowers one or two at the base of the racemes, and with a 6-lobed calyx; capsule short-pedicelled, somewhat depressed, 8–10 mm. in diameter, densely pubescent with long white hairs; seeds subglobose, 3 mm. long, smooth.

Rocky woods on the Upper Hondo, central Texas. Summer.

This very distinct and peculiar *Tragia* is not referable to any species known to me, but is most nearly related to *T. urens* L., from which it differs in being smooth, and in having few-flowered racemes, 3-lobed staminate calyxes, and larger leaves.

Specimens examined: TEXAS: The only specimens seen are those of the type, collected on the Upper Hondo, by *J. Reverchon* 1594, June, 1885.

LOBELIA PUBERULA PAUCIFLORA n. var.

Stems 6–10 dm. tall, simple, very slender, densely white-

pubescent. Leaves elongated, oblong-lanceolate, entire or glandular-toothed, rather few on the stems; flowers few, 3 to 9, scattered along the stem, 2.5–5 cm. apart; sepals densely pubescent and bristly with long white hairs; corolla azure blue, about 3 cm. long; tube more than twice as long as the sepals; hypanthium densely hispid with long bright white hairs.

Sandy swamps near the coast, Florida to Texas. Summer and autumn.

This is evidently related to *L. puberula* Michx., but differs conspicuously from that species in the taller, more slender, simple stems, longer leaves, and especially in the fewer flowers, which are much larger.

Specimens examined: TEXAS: Swan, *Reverchon* 3206, September 17, 1902, type. FLORIDA: Without locality and date, *Chapman*. LOUISIANA: Without locality and date, *Hale*.

XANTHIUM BUBALOCARPON n. sp.

Stems very stout, much branched and spreading, about one meter tall. Upper part of the stem and the petioles very rough, covered with stout white papillae; petioles 5–15 cm. long, stout; leaf blades broadly triangular, 8–20 cm. wide, 3- to 5-lobed, dentate, very thick, rough-scabrous on both surfaces; burs pubescent, ovoid, clustered in the axils of the upper leaves, and in terminal racemose clusters, 2.5–4 cm. long, including the short beaks, 2–3 cm. wide, including the prickles, the short hispid beaks 6–8 mm. long, nearly straight, hooked at the apex, equalling or a little shorter than the very dense subulate, slightly uncinate prickles, which are about one-third as long as the diameter of the bur, and hispid nearly to the middle with yellowish-brown hairs, the prickles and the pubescence usually entirely concealing the body of the bur.

Prairies and barrens, western Arkansas and eastern

Texas, abundant, where it is called Buffalo Bur, whence the specific name. Autumn.

This very distinct species is more nearly related to *X. speciosum* Kearney, but is easily distinguished from that species by the much larger burs which are of an entirely different shape.

Specimens examined: TEXAS: Dallas County, *Bush* 1185, September 29, 1900, type. ARKANSAS: Fulton, *Bush* 2408, April 22, 1905, seedlings, with burs still attached.

ANTENNARIA GREENEI n. sp.

Floccose-woolly, stoloniferous, fertile and sterile plants in separate patches. Flowering stems stout, 1–2.5 cm. tall; basal leaves cuneate-spatulate, obtuse, cuspidate, distinctly 3-ribbed, long-petioled, silvery beneath, dark green above, becoming nearly smooth on the upper surface, 5–6 cm. long, including the long slender petiole, 1.5–2.5 cm. wide, those of the stolons cuneate-spatulate, acuminate, apex cuspidate, tapering from about the middle to each end, thickly covered beneath with silvery tomentum, appressed-pubescent above, strongly 3-ribbed, 8–13 cm. long, including the long slender petiole which is as long as the blade or longer, and 2.5–4 cm. wide; stem leaves sessile, oblong, obtuse, or the upper acute, cuspidate; heads 6 to 9 in corymbose clusters, 6–8 mm. broad; involucre about 6 mm. high, the outermost bracts obtuse, the inner lanceolate, acute, all brownish and greenish, and pubescent at base, above with white tips; achenes minutely glandular. Staminate plants about 1 dm. tall. Basal leaves similar to those of the fertile plant; stem leaves mostly linear-lanceolate; heads smaller, 6–7 mm. broad, in a capitate cluster; bracts oblong-spatulate, brownish and greenish and pubescent at base, the upper dilated portion white, erose-dentate all around the upper portion.

Damp, sandy woods along the Trinity River, central Texas. Early spring.

The species here proposed is most nearly related to *A. occidentalis* Greene, but is distinguished from that species by the exceedingly long-petioled leaves, which are about twice the length of those of that species, and much more pointed at apex.

Specimens examined: TEXAS: Dallas County, *Bush* 644, May 7, 1900, type; *Reverchon* 330, April 1, 1900, type; March, 1880, type.

SILPHIUM REVERCHONI n. sp.

Stems apparently tall, very hispid with long white hairs which arise from papillae, much branched, the branches elongated. Leaves alternate; blades lanceolate to linear-lanceolate, 5–10 cm. long, dentate-serrate or the uppermost nearly entire, both faces pilose with long white papillate hairs like those of the stem; lower leaves long-petioled, ovate-lanceolate, acute, sinuate-dentate or entire, with dense short pilose hairs which arise from papillae; petioles slender, terete, with long white papillate hairs; heads showy, very large; involucres campanulate, 2.5 cm. high; bracts lanceolate, acute, ciliate, densely papillose-hispid on the back, the outer ones 3 cm. long, the inner shorter, obtuse; rays about 20, 3-4 cm. long, hispid on the nerves, and ciliate; achenes not seen.

Dry sandy soil, eastern Texas. Spring.

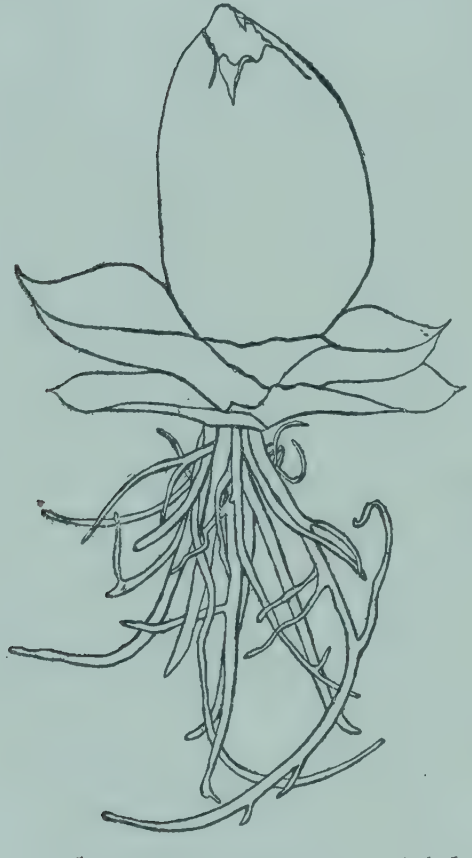
Clearly related to *S. Gatesii* Mohr, but is abundantly distinct in the larger heads, longer papillose-hispid hairs, different type of leaves and different root-leaves.

Specimens examined: TEXAS: Troupe, *Reverchon* 3342, May 8, 1902, type; Lindale, *Reverchon*, June 9, 1903.

ASCIDIA IN GASTERIA AND AGAVE.

BY J. ARTHUR HARRIS.

In the summer of 1905 Mr. C. H. Thompson, in charge of the collection of succulents at the Missouri Botanical Garden, called my attention to a peculiarity of two of several young plants of *Gasteria* grown from seed received



1. G. BRACHYPHYLLA, × 1.

2. G. BRACHYPHYLLA, × 1.

3. G. BRACHYPHYLLA, × 1.

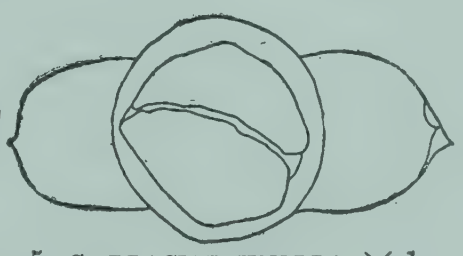
from the botanical garden at Palermo under the name *G. brachyphylla*.

The general appearance of the abnormal plants is shown in figures 1 and 2, while for the sake of comparison a normal specimen from the same lot is shown in figure 3. Figure 1 represents the anomaly at its best. The four earlier

leaves are of the normal form, while the remainder of the plant is composed of an ovate organ of the same texture as the leaf, but continuous throughout except for a small, irregular opening at the apex through which a younger leaf is visible. The first impression was that the structure in question consisted of an ascidium formed by the fusion of two leaves as has been described for *Crassula arborescens*,* but Mr. Thompson, upon looking through the rather large series of young plants then growing, found two interesting forms, one of which is represented in figure 4, which were cultivated under the names *G. verrucosa* and *G. trigona*. These seem to show a folding in of one or both margins of the leaf in a way which might indicate that the open calyptra originates from a single leaf developing from a primordium extending entirely around the vegetative point of the axis. In these two cases the tip of the leaf exhibits two apiculae and the same is apparently true for the plant represented in figure 1, though here the irregularity of the opening at the apex precludes a final decision.

4. G. TRIGONA, × 1.

A transverse section near the base of the ascidium shows it to be composed of a layer of tissue slightly thicker on one side, surrounding two leaves of normal form, but not of the normal distichous arrangement, as may be seen from the diagram, figure 5. This anomaly of the leaf arrangement cannot be regarded as having any special significance since it is frequently to be observed in otherwise normal individuals



5. G. BRACHYPHYLLLA, × 1.

* Morren, C. Bull. Acad. Roy. Sci. Belg. 19³ : 458–462. *pl.* 1852.

of *Gasteria*. It seems probable that the ascidium originated from a continuous ring of meristematic tissue.

The second specimen, figure 2, was seen by the writer only in its present condition, but according to Mr. Thompson it was earlier exactly comparable with the one described above, and reached its present condition by the rupturing of the calyptra.

A comparable anomaly was seen in one of the leaves of a young plant of *Agave Americana variegata* growing at the Garden. Figure 6 renders any description unnecessary. In the herbarium of the Garden is a photograph of another young plant belonging to a different species of the section Americanae of the same genus, in which precisely the same condition prevails.

6. A. AMERICANA, × ¼.

Foliar ascidia are familiar to biologists in several insectivorous plants. The great interest attaching to these and the curious appearance presented by teratological ascidia have caused the latter to receive particular attention among plant anomalies and more than one monographic treatment has appeared. In 1838 Morren * suggested a classification of all the foliar ascidia known to him. He again published † on this subject in 1852, presenting an elaboration of his classification of teratological forms and citing all cases known to him. In 1863 Kickx ‡ modified and extended the classification proposed by Morren. From this paper

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* Morren, C. Bull. Acad. Roy. Sci. Brux. **5**: 430–442, 582–586. 1838.— Ann. Sci. Nat. II. **11**: 119–128. 1839.

† Morren, C. Bull. Acad. Roy. Sci. Belg. **19**^{3}: 444–462. 1852.

‡ Kickx, J. Bull. Acad. Roy. Sci. Belg. II. **16**: 625–632. 1863.

the treatment in the work of Masters * is largely taken, though some differences are to be noted. Penzig's † lists are extensive, but his arrangement is purely a systematic one.

Since Masters's work no general treatment has appeared but several individual cases have been described and some important papers bearing directly or indirectly on the subject have been published. Of these, one by Penzig ‡ and three by De Candolle § should be especially mentioned.

None of the ascidia described in these papers are at all comparable with those here discussed except, perhaps, those of *Tulipa*, *Polygonatum*, *Convallaria*, *Lilium*, *Acanthophippium* and *Vanilla*.

The calyptriform ascidium of *Tulipa Gesneriana* was first mentioned by Hincks ‖ who described it as "a specimen of *Tulipa Gesneriana*, in which the leaf on the stem, folding around it, had cohered by its edges, so as to completely enclose the flower-bud, which, as it enlarged, carried up the upper part of the leaf, like the calyptra of a moss." Saint-Pierre ¶ describes a similar anomaly.

Hincks also mentions a plant of *Convallaria multiflora* "in which the two lowermost leaves cohered by their edges into a sort of a bag, which considerably obstructed the growth of the stem."

Kicks merely mentions a tubiform monophyllous ascidium in *Lilium lancifolium*. He also observed ** a fusiform-cylindrical ascidium of nearly two decimeters in length on the leaf of *Acanthophippium bicolor*. James ††

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* Masters, M. T. Vegetable Teratology. London. 1869.

† Penzig, O. Pflanzen-Teratologie. Genua. 1890–'94.

‡ Penzig, O. Malpighia. **16**: 167–175. *pl. 4–6*. 1902.

§ De Candolle, C. Bull. Soc. Bot. Genève. **8**: 61–69. 1897; **9**: 1–51. 1899. — Bull. Herb. Boissier. II. **2**: 753–762. *pl. 8–9*. 1902.

‖ Hincks, W. Rept. Brit. Ass. Adv. Sci. **7**: 120. 1839.

¶ Saint-Pierre, G. Bull. Soc. Bot. Fr. **1**: 63. 1854.

** Kickx, J. Bull. Acad. Roy. Sci. Belg. **18**[1]: 591. 1851.

†† James. Gard. Chron. n. s. **15**: 799. 1881.

found an ascidium in the leaf of *Masdevallia Lindeni* but no description is given. Jacob de Cordemoy * describes an anomaly in *Vanilla planifolia* which may be exactly comparable with those seen in *Agave* and *Gasteria*. The branches were terminated by an erect, slightly flattened, hollow, fusiform body of eight centimeters in length and one centimeter in thickness. A histological examination showed this organ to be foliar in nature, but the description of the solid stalk of the fusiform body does not permit of a final decision as to the comparability of the tubiform ascidia under consideration.

The condition in *Polygonatum multiflorum* is of interest in this connection. The first record is that of Morren † of a monophyllous, tubiform ascidium. Later he describes ‡ a specimen in the collection of Hincks as a series of three ascidia through the center of which passed the axis bearing normal leaves and flowers. "Qu'on s'imagine donc un cornet foliacé qui se termine par deux oreillettes latérales et opposées, servant d'étui à deux autres cornets ayant aussi chacun deux oreillettes opposées, et au-dessus d'eux un bouquet de feuilles et de fleurs, et on aura la représentation de cette belle monstruosité, de cette curieuse anomalie." Morren thought it remarkable that the ascidia should have been formed by the fusion of two leaves but this point was, he considered, established by the presence of the two auricles which formed about the terminal fourth of the total length of the ascidia. To give rise to such ascidia the position of the three pairs of leaves must have changed from alternate to nearly opposite.

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* Jacob de Cordemoy, H. Rev. Gén. Bot. **11**: 258–267. *fig. 54–58.* 1899.

† Morren, C. Bull. Acad. Roy. Sci. Brux. **5**: 437, 439, 586. 1838.— Ann. Sci. Nat. II. **11**: 124, 126. 1839.

‡ Morren, C. Bull. Acad. Roy. Belg. **5**: 584–585. 1838; **19**^{3}: 456, 458. 1852.

Puel and Saint-Pierre * also observed an ascidium in this form. The fourth leaf was transformed into a sack with a small opening at the tip through which the stem extended. The fifth leaf was normal while the sixth also had the margins partly fused. The veins of the leaf forming the main ascidium are described as of equal size.

It is now quite impossible to draw any conclusions concerning the ascidia described as diphyllous in *Convallaria* and *Polygonatum*, but the normal arrangement of the leaves in these forms and the condition found in the other Monocotyledons in which ascidia have been found suggests that possibly these anomalies are monophyllous in origin.

Leaves showing a more or less complete longitudinal division into two component parts are among the commonly described foliar anomalies. There are two processes by which such structures might arise: — by the fusion of two adjacent primordia or by the longitudinal division of one already formed. The numerous cases which have been described have been referred, by implication at least, to one of these categories. Pax † and Klein ‡ have suggested criteria for determing the probable method of development of any individual case, but since the necessary data are wanting a correct interpretation of most of the published descriptions is quite impossible. But for our present purpose it is sufficient to note that either the production of two primordia in the region where only one normally occurs or the broadening of the single primordium by division increases the total width of the meristematic region from which a foliar organ is developing. If this region comes to extend entirely around the axis, tubiform ascidia such as those described in this paper may result.

A broadening of the leaf accompanied by longitudinal

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* Puel and Saint-Pierre. Bull. Soc. Bot. Fr. **1**: 62–63. 1854.

† Pax, F. Allg. Morph. Pfl. 92. 1890.

‡ Klein, J. Jahrb. Wiss. Bot. **24**: 425–498. *pl. 13–18*. 1892.

division for a greater or less distance or the more or less complete fusion of two original primordia has been observed in *Musa Ensete* by Meyran,* in *Tulipa Gesneriana* by Lange,† in *Ophrys aranifera* by Saint-Pierre ‡ in *Orchis maculata* by Clos,§ in *Strelitzia Reginae* by Massalongo,‖ in *Richardia aethiopica*, *Colocasia undulata*, *Lolium perenne* and *Potamogeton plantagineus* by Braun¶ and perhaps other cases from the teratolgical literature might be referred to these categories. I have seen the same phenomenon in a specimen of *Agave* sp. growing in the Missouri Botanical Gardens and in the herbarium is a leaf of *A. picta* showing the same anomaly. While such divided leaves may not be described as intermediate between the normally developed leaf and the tubiform ascidia — which have as yet been observed only in the Monocotyledons — it seems possible that there is some similarity in their mode of development.

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* Meyran, O. Bull. Soc. Bot. Lyon. II. **3**: 123–124. 1885.
† Lange. Bot. Tids. **7**: 209. 1873–74.
‡ Saint-Pierre, G. Bull. Soc. Bot. Fr. **23**: xxxvi–xl. 1876.
§ Clos, D. Bull. Soc. Bot. Fr. **36**: ccx. 1889.
‖ Massalongo, C. Nuovo Giorn. Bot. Ital. **20**: 283. *pl. 16*. 1888.
¶ Braun, A. Sitzb. Ges. Naturf. Freunde, Berlin. **1871**: 7.

PROLIFICATION OF THE FRUIT IN CAPSICUM AND PASSIFLORA.

BY J. ARTHUR HARRIS.

The appearance of a recent paper on the influence of cold in the production of cleistogamy and teratological phenomena in *Solanum Melongena* and in *Capsicum annuum*, by Dr. G. Mottareale,* has induced me to put into print notes and drawings made some years ago at the Missouri Botanical Garden. These observations were made upon a very large series of fruits from plants grown in the open and are consequently interesting for comparison with those studied by Mottareale. Since they refer chiefly to an anomaly which he was not able to study extensively it seems best to present the notes in full with most of the figures as originally prepared. Observations on prolification of the fruit of *Passiflora* are also added.

Capsicum.

The material studied by Mottareale was grown under the following conditions. In three large greenhouses the principal plants cultivated were *Phaseolus vulgaris*, *Cucumis sativus*, *Cucurbita Pepo*, *Solanum Melongena*, *Capsicum annuum*, *C. grossum*, and *Lycopersicum esculentum*. During the early part of the winter the heating plant had not yet been installed, but owing to the mild climate the plants made a vigorous vegetative growth and were beginning to produce normal flowers when, about the middle of December, two or three nights of cold wrought havoc with them. The egg plants and the peppers lost their flowers and most of their leaves, and the more tender apical shoots blackened and dried. But the vitality of the plants was

* Mottareale, G. Ann. R. Scuola Sup. Agr., Portici. **6.** 1904.

not entirely destroyed and when provision for a suitable temperature was made, the vegetative organs gradually regained their former luxuriance. But the sexual organs were very teratological in nature, and these anomalies of flower and fruit Mottareale considers the result of the conditions of temperature to which the plants were subjected.

Of the anomalies of the calyx, corolla and stamens, only pistillody of the stamens need be mentioned here. In *Capsicum* adesmy of the carpels was noted in several cases but we may confine our attention to the internal structure of the fruit. Mottareale saw diaphysis of the fruit — the production of another imperfect fruit from the center of the thalamus, and ecblastesis — the production of accessory fruits from the axils of the carpels. Both anomalies were seen in some fruits. He found the seeds either normal, abortive, more or less foliaceous, or tending to assume the form of a carpel.

The evidence for referring these anomalies to the influence of the cold seems unsatisfactory. He himself tried for two successive years to reproduce the result but without success. Furthermore, anomalies resembling those he describes are not infrequently seen in *Lycopersicum*, *Solanum* and *Capsicum*.* Confining our attention strictly to the fruit we note the occurrence of pistillody of the stamens in all three genera, the occurrence of supernumerary whorls of carpels in *Lycopersicum*, the rupturing of the fruit wall by the placentae in *Solanum Melongena*, and the production of carpel-like bodies inside the fruit of *Capsicum*.

Terracciano † observed two types of prolification in *C. annuum*. In one form the walls of the fruit, terminated by a hollow tubiform style open at the top, showed five gibbous evaginations. Internally the fruit

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* Penzig, O. Pflanzen-Teratologie. **2**: 169–174. 1894.

† Terracciano, N. Nuovo Giorn. Bot. Ital. **10**: 28–34. *pl. 1*. 1878.

produced no seeds but contained five smaller fruits, likewise without seeds and with short styles and almost obsolete stigmas, disposed upon the apex of the thalamus. In the other type the fruits were quite normal externally and bore numerous seeds but produced also a single included fruit at the top of the axis. According to Penzig, Borbás describes central prolification in *Capsicum*. Halsted * saw, in the same genus, a small included fruit which originated from the apex of the axis, and Viviand-Morel † figures an almost identical case, while Raymondaud ‡ also figures an internal fruit. Penzig § reports central prolification as especially common.

In 1902 a considerable plot was devoted to the cultivation of capsicums at the Missouri Botanical Garden. Fruit-like bodies were noticed occasionally during the summer in those gathered for table use, and late in the autumn the entire crop was gathered and the fruits were dissected for the purpose of determining the frequency of the anomaly. Other material was secured for the purpose of comparison during the present year, but since it yielded only corroborative evidence and was not large enough in amount to permit of statistical discussion the following statements are based on the series collected in 1902.

From the literature cited above it seems that the carpel- or fruit-like structures may originate in three ways: — by central prolification or diaphysis, by prolification from the axils of the carpels or ecblastesis, and by the transformation of the primordium of an ovule into a carpellary body. All of these phenomena have been seen in other genera of plants and are to be regarded as representing valid categories, but it proved impossible to divide the anomalies

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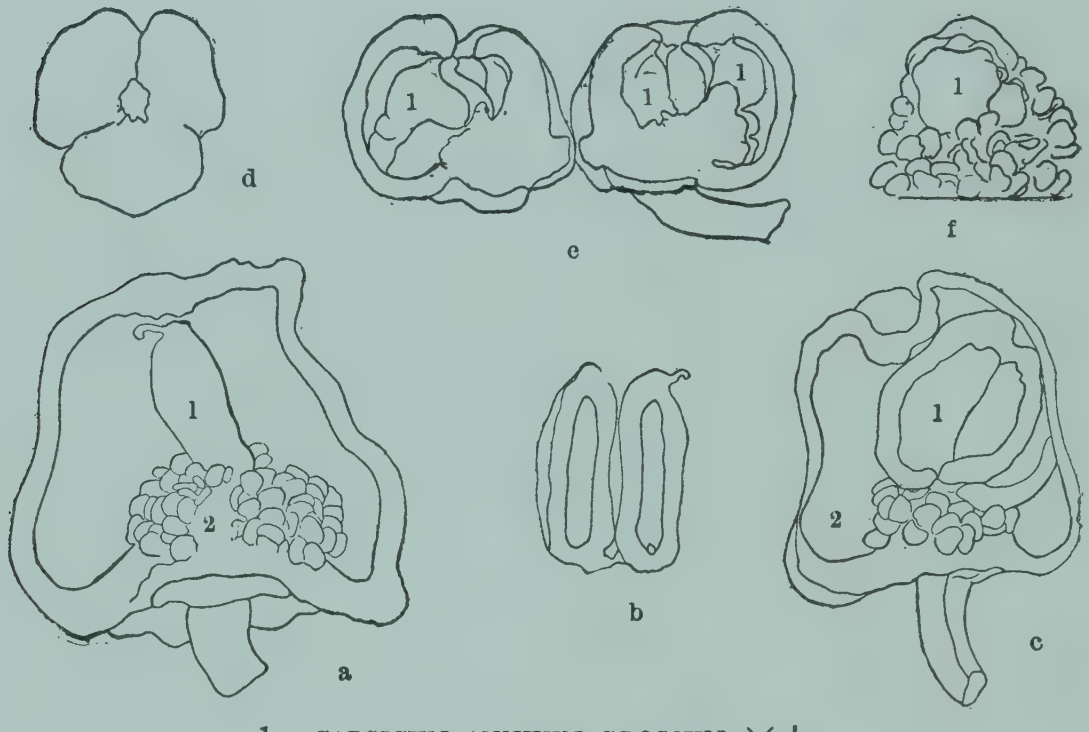
* Halsted, B. D. Bull. Torr. Bot. Club. **18**: 151. *fig.* 1891. — Pop. Sci. Mo. **42**: 321–322. *fig. 16.* 1893.

† Vivland-Morel, J. V. Lyon Horticole. **24**: 382. *fig.* 1902.

‡ Raymondaud, E. Rev. Sci. Limousin. **12**: 369–372. 1904.

§ Penzig, O. *l. c.*

found in over three hundred abnormal fruits examined into these classes. It is quite impossible to determine whether a given carpel-like body was produced from a bud in the axil of a carpel or indeed from an adventitious bud on any portion of the carpel, or from a primordium which normally would have developed into an ovule. It is no easier to ascertain whether the accessory organ was produced from the apex of the torus or from a neighboring ovule primordium. The nature of the *Capsicum* fruit precludes



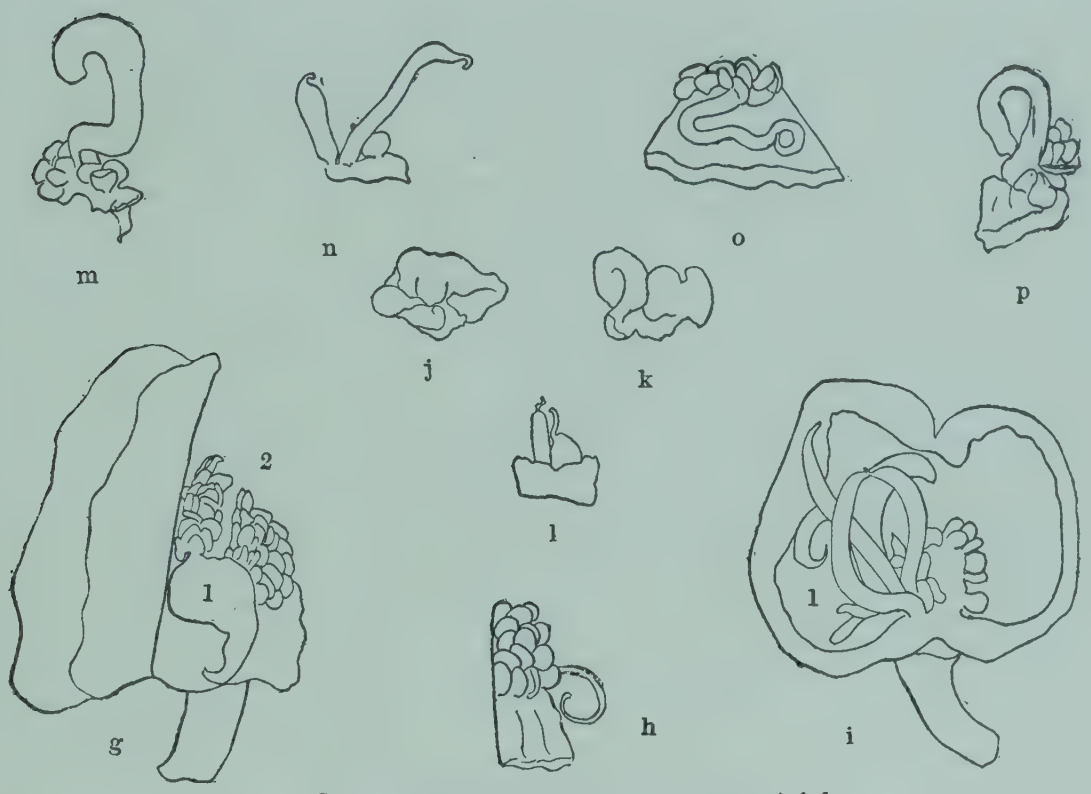
1. CAPSICUM ANNUUM GROSSUM, × ½.

the determination of some points which may be studied in other forms.

The margins of the included carpel-like bodies were in all cases completely closed, and not open as has been described in some cases of carpels produced by prolification. The smaller ones showed no cavity whatever but were solid throughout. In form they varied from an irregularly contorted body through an almost perfectly formed sterile fruit, comparable in shape with the one in which it

was produced, to linear structures from a few millimeters to two centimeters or more in length, terminated by a minute style.

Histologically the similarity of the carpel-like bodies to the wall of the fruit is very great. Both show the exceedingly heavy epidermis and the large-celled parenchymatous ground tissue. The bodies show one or more vascular bundles similar to those of the wall of the fruit. When fresh sections are examined, numerous chromoplasts are



2. CAPSICUM ANNUM GROSSUM × ½.

seen in both but they are generally more abundant in the wall of the fruit.

Since the appearance of the teratological papers of de Vries, one of the chief objects of teratological studies is the determination of the frequency of occurrence of the various anomalies. The fruits examined by the writer belong to twenty named varieties but here only sixteen which have been described by Irish in his Revision

of the Genus Capsicum * or in a later paper †, will be included.

In the accompanying table the garden varieties are grouped under the botanical varieties recognized by Irish. The number of normal fruits and the number which contained carpel-like bodies, as well as the percentage which the latter are of the total number examined are given for each variety. No attempt is made to classify these bodies according to form or origin.

TABLE A. DISTRIBUTION OF ANOMALIES IN CAPSICUM.

VARIETY.	Normal.	Abnormal.	Per cent. Abnormal.
Capsicum annuum acuminatum.			
Chilli	105	0	....
Long Cayenne	200	1	.5
Long Yellow Cayenne	250	0	....
Yellow Nepal Chilli	176	1	.5
Capsicum annuum longum.			
County Fair	200	0	....
Long Red	165	0	....
Capsicum annuum grossum.			
Monstrous	917	167	15.4
Ruby King	40	0	....
Golden Dawn	73	6	7.5
Bell	89	19	17.5
Golden King	150	33	18.
Squash, or Tomato Shaped	133	11	7.6
Capsicum annuum abbreviatum.			
Red Etna	250	0	....
Red Wrinkled	223	0	....
Burpee's Mikado	258	88	25.4
Capsicum annuum cerasiforme.			
Cherry	198	16	7.4
Total	3,427	342	9.

* Irish, H. C. Rept. Mo. Bot. Gard. **9**: 53–110. *pl. 8–28.* 1899.

† Irish, H. C. Proc. Soc. Prom. Ag. Sci. **23**: 63–64. 1902.

Some suggestive points are to be gathered from this table. The slender-fruited varieties classified under *C. annuum acuminatum* and *C. annuum longum* show only two cases of prolification although nearly 1,100 fruits were dissected. Of the 2,671 fruits examined from the ten garden varities of *C. annuum grossum*, *C. annuum abbreviatum* and *C. annuum cerasiforme*, 340, or 12.7%, show prolification in some form. But that the relative length and diameter of the fruit is not the only factor involved is rendered probable by the three exceptions among these ten short-fruited varieties. The absence of abnormal fruits in Ruby King may be a chance result due to the small series of material examined, but this explanation cannot be offered for Etna and Red Wrinkled.

The chief conclusions to be drawn from the literature and from the present series of observations are the following.

The included bodies are doubtless formed by the three processes heretofore recognized as giving rise to intracarpellary fruits, namely diaphysis, ecblastesis, and pistillody of the ovule primordium, but the fruit of *Capsicum* is not suitable for a determination of the number of cases to be referred to each category.

In form the bodies vary greatly, but two main types — rounded or irregularly contorted, and linear — are to be recognized. The more or less isodiametric form is almost invariably found at the apex of the torus or at the base of the seed-bearing region. The linear form may occupy any position.

Histologically the bodies are very similar to the wall of the fruit.

Prolification of the fruit, using the term to cover all three phenomena mentioned above, is very common in several garden varieties of *Capsicum*. It is practically wanting in the slender-fruited forms, although some varieties form exceptions to this rule.

The foregoing facts preclude any conclusions concerning the influence of environmental conditions, until careful statistical studies have been made. These must take into consideration ancestry as well as environment.

Passiflora.

A number of observations have been published on abnormal fruits in *Passiflora*, but since all the work has been done independently, I take this opportunity of bringing together the literature and of presenting further observations made upon a much larger series of material than has been examined heretofore.

Clos* describes the prolification of the fruit of *P. gracilis*. He found two types. In one there were three pedicels each with three styles and in the other a single pedicel terminated by three styles. Salter† describes an abnormality in the ovules of *P. palmata* and *P. caerulea*. Lindberg‡ records proliferous fruits in *P. gracilis*. His descriptions agree with those of other authors. Bernoulli§ records a case of prolification in *P. serratistipula* in which a slightly abnormal flower was produced in an apparently normal fruit. He also states that in the section Granadilla, a short, filamentous projection is frequently to be seen at the bottom of a fruit-cavity. Masters‖ describes a fruit of *P. quadrangularis* "wherein small flower-buds were found springing from the placentas intermixed with the seeds." Hildebrand¶ notes fruits with

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* Clos, D. Mém. Acad. Imp. Sci. Inscript. Belles-Lettres, Toulouse. V. **3**: 113. 1859.

† Salter, S. I. Trans. Linn. Soc. **24**: 143–150. *pl. 24*. 1863.

‡ Lindberg, S. O. Öfvers. Finska Vetensk.-Soc. Förh. **10**: 15–16. 1867.

§ Bernoulli, G. Bot. Zeit. **27**: 21–23. 1869.

‖ Masters, M. T. Trans. Linn. Soc. **27**: 607. 1871.

¶ Hildebrand, F. Bot. Centralbl. **9**: 401–404. *pl. 1*. 1882.

four carpels. He figures and describes in considerable detail prolification in fruits of *P. gracilis* in the Botanical Garden at Freiburg. He finds the produced axis bearing an indefinite number of carpels, sometimes over sixteen, having more or less completely developed stigmas and producing on their edges, which cohere in various degrees, a limited number of ovules. In several cases the main axis bore a lateral branch, which in turn produced a number of carpels of diverse degrees of development. Wigand * describes the structure of the enclosed shoot of *P. gracilis* in detail. Müller † describes briefly prolification of the fruit of *P. alata*. In several fruits of this species he found a perfectly developed flower bud. The fruits contained an abundance of good seeds. A plant raised from these had produced, up to the time of the writing of his paper, only normal fruits.

In the summer of 1902, vigorous specimens of *P. gracilis* were growing in the Missouri Botanical Garden in part in the Cycad house and in part over a lattice in the open air. My observations are based upon the examination of 167 proliferous fruits secured by dissecting 4,240 fruits. The material was collected in four lots, the first taken from the vines growing in the greenhouse and the last three from those on the outside. Lots one and two were gathered early in October, the third was taken October 25, and the fourth lot about five days later. The distribution of the material was as follows: —

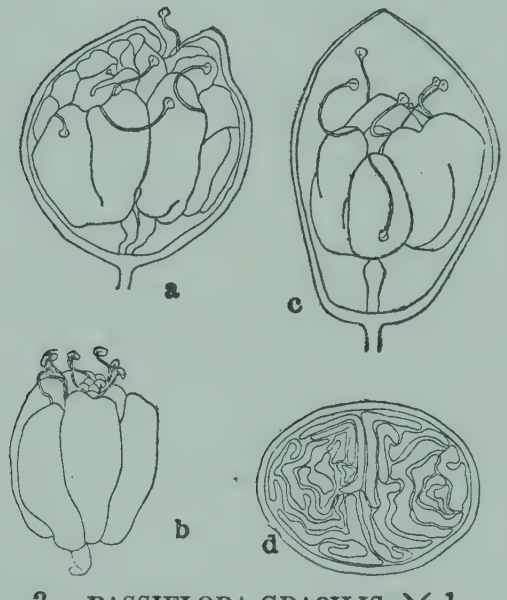
Lot I.	558 normal,	39 proliferous	— 6.5 per cent.
Lot II.	1402 normal,	56 proliferous	— 3.9 per cent.
Lot III.	1239 normal,	38 proliferous	— 2.9 per cent.
Lot IV.	874 normal,	34 proliferous	— 3.7 per cent.
Total.	4073 normal,	167 proliferous	— 3.9 per cent.

* Wigand, A. Bot. Hefte. Forsch. a. d. Bot. Gart. Marburg. **2**: 125-126. 1885.

† Müller, F. Flora. **73**: 332-333. *fig.* 1890.

As pointed out by earlier writers, the prolification consists in the production from the base of the fruit of a stalk, or sometimes two or more stalks bearing a variable number of carpels closely packed together as may be beautifully seen in a cross section of the fruit. The margins of the carpels are fused in various degrees or free. A few ovules are sometimes produced. For other details the accompanying figures may be consulted.

Of 125 proliferous fruits dissected, 100 had only a single central stalk while 25 had more. In several cases small bud-like or filamentous processes were seen near the base of the stalk bearing the accessory carpels, but when these produced no differentiated carpels they were not counted. The determination of the number of the included carpels is sometimes rather difficult owing to the varying degrees of fusion of the members of the outer whorls and the small size of those of the inner ones. The best criterion seems to be the number of styles. These seem to be independent of the fusion of the carpels and they are usually well developed even in the smallest members of the inner whorls. The number of carpels counted in the 25 fruits containing more than one carpel-bearing pedicel was: — 22, 22, 33, 35, 38, 42, 44, 46, 46, 46, 48, 49, 49, 51, 51, 55, 57, 64, 64, 66, 71, 72, 83, 90, 90. The number of carpels in the 100 fruits containing only a single carpel-bearing pedicel is shown in the accompanying table. The smallness of the series and the fact that the material was derived from two habitats renders any biometric discussion unprofitable.



3. PASSIFLORA GRACILIS, × 1.

TABLE B. NUMBER OF CARPELS IN ABNORMAL FRUITS OF PASSIFLORA.

N	F	N	F	N	F	N	F	N	F
3	3	18	3	27	1	36	3	46	2
4	18	19	2	28	1	37	4	47	1
5	3	21	4	29	4	38	2	48	1
6	8	22	2	30	1	39	2	55	1
7	3	23	1	31	3	41	3	57	1
13	1	24	2	32	1	42	1		
14	1	25	2	33	1	43	2		
15	3	26	3	34	4	45	2		

A rupturing of the wall of the fruit in the abnormal examples was very frequent, amounting to about 30% in one of the lots collected in the open. A very noticeable difference between the material growing in the greenhouse and in the open was the very much smaller size of the included group of carpels in the former. In only about 5% of the examples collected in the Cycad house was the wall of the fruit ruptured by the included body, which was usually quite small and simple, while in the material grown outside the inner group was usually large and very complicated in structure, being composed of a great number of irregularly arranged carpels.

It is interesting to note that prolification of the fruit has been seen by three observers in another member of the Passifloraceae, *Carica Papaya*. Müller* figures a sterile fruit containing a large central fruit with numerous ovules. According to Houard,† Prain ‡ figures a specimen containing numerous secondary fruits. Urbina§ discusses an example in which the cavity in addition to the normal black seeds was filled by six conical, conduplicate

* Müller, F. *l. c.*

† Houard, C. Rev. Gén. Bot. **18**: 131. 1906.

‡ Prain, D. Journ. As. Soc. Bengal. **1895**: 196–198. *pl. 4–5.*

§ Urbina, M. La Naturaleza. **3**: 359–360. *pl. 19.* 1900.

carpellary bodies of 8 to 10 centimeters in length and 4 to 6 centimeters in diameter, bearing abortive ovules. The center of the fruit was occupied by a cylindrical body of about 14 centimeters in length and 4 to 5 centimeters in diameter, bearing five branches near the base. Urbina considers this fruit to be composed of three whorls, each of five carpels. The lowermost forms the normal fruit. The second is represented by five included carpels, of which one is divided longitudinally. The third whorl, which is much more rudimentary, appears as the central column with its basal branches.

Diaphysis and ecblastesis of the fruit, while not so common as many other anomalies, need not be considered further here. The transformation of the primordium of an ovule into a carpel-like body is still rarer. The only instances known to me are the *Cheiranthus Cheiri* described by DeCandolle * and Masters, † the Barbarossa grape figured by Masters, ‡ the *Sinapis arvensis* described by Baillon, § and the *Dianthus* figured by Berkeley. ‖ A careful search through the older discussions of the evidence of teratology on the homologies of the ovule would, perhaps, disclose other cases.

Such anomalies as the present ones are interesting in connection with Sach's theory of "material and form," to which Goebel is inclined to attach much significance.

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* DeCandolle, A. P. and A. DeCandolle. Nouv. Mém. Soc. Helv. Sci. Nat. **5**. *pl. 5*. 1841.

† Masters, M. T. Veg. Ter. 182. *fig. 94-95*. 1869.

‡ Masters, M. T. *l. c.* 182-183. fig. 96-97.

§ Baillon, H. Adansonia. **8**: 351-353. *pl. 12*. 1862-'63.

‖ Berkeley, M. J. Gard. Chron. **1850**: 612. *figures*.

EXPLANATION OF TEXT FIGURES.

All of the figures are diagrammatic.

Figure 1. — *Capsicum annuum grossum.* a — c, "Monstrous." d — e, "Golden King." f, "Bell." In a and c the carpel-like bodies (1), seen at the apex of the torus surrounded by seeds (2), probably originated by central prolification. In b the body from a is seen in longitudinal section, showing the thickness of the walls. In c is also to be seen a carpel-like body (3), probably originating by pistillody of an ovule. Slight adesmy of the carpels is represented, from above, in d, and in longitudinal section in the two halves of the same fruit, in e. The torus of this fruit was abnormally large and almost the entire cavity of the fruit was filled with large, irregularly rounded fruit-like bodies (1). The origin of these bodies is uncertain. In f an irregularly rounded fruit-like structure (1) is seen at the apex of the torus surrounded by seeds.

Figure 2. — *Capsicum annuum grossum.* g—h, "Bell." i—l, "Golden King." m—n, "Monstrous." o—p, "Bell." In g half of the fruit wall is removed to show the torus bearing seeds (2), and a large flattened carpel-like body (1), originating by ecblastesis or by pistillody of an ovule. In h the same condition prevails but here the body is linear. In i seven linear bodies (1), originating by ecblastesis or by pistillody of ovules, are seen. j—k represent various forms of carpel-like bodies removed from the fruits, sometimes with a block of the torus.

Figure 3. — Central prolification of the fruits in *Passiflora gracilis.* a, Fruit with two carpel-bearing pedicels. b, Carpel-bearing pedicel removed from fruit. c, Fruit with single included pedicel. d, Diagram of cross section of fruit, with two carpel-bearing pedicels, such as is shown in a, showing irregular arrangement of included carpels.

FASCIATION IN OXALIS CRENATA AND EXPERIMENTAL PRODUCTION OF FASCIATIONS.

BY HENRI HUS.

Oxalis crenata is largely grown in South America, more particularly in Peru, where it is known as "Oka," and in Bolivia where it flourishes on the Puna, a plateau 12,000 feet above sea level. It bears tubers (pl. 17, f. 1) three to four inches long and about an inch in diameter. They contain much starch and are used as food after having been exposed to the sun for two or three days and then boiled for about twenty minutes in water containing some cooking soda.

During four years more or less I had the opportunity to observe this plant in the experimental grounds at Berkeley, California, where it was grown from tubers received from the Botanic Garden at Sydney, N. S. W. Each year a number of fasciations of the stem made their appearance, but only in the latter part of the season. Some of the plants of the 1903 crop were chosen for purposes of illustration. Not only did they show the more normal type of fasciation, *i. e.*, a fasciated mainstem and branches, the majority of which are normal (pl. 18), but there also occurred instances where the entire plant was fasciated in the most fantastic manner and even bore tubers at various places on the aërial stem (pl. 19). Many of the tubers were likewise fasciated.

From Dr. Otto Kuntze it was learned that this fasciated condition is the one most frequently met with in Bolivia, and all plants of *Oxalis crenata* seen by him at Cochabamba were of this character. * There are no means of knowing

* Penzig in his Pflanzen-Teratologie mentions a fasciation of *Oxalis crenata* as enumerated by Crépin in Recueil de faits tératologiques, 2, (Bull. de la Soc. Roy. de Botanique de Belgique. 4: 276-278. 1865), but which was not found when the paper in question was referred to.

with exactitude what was the nature of the ancestors of our plants in the Sydney Botanical Garden, but for the present purpose the data gathered at Berkeley are sufficient.

The specimens of *Oxalis crenata* grown at Berkeley confirm in the most striking manner the views on the transmissibility of fasciations which at the present time are more generally held than formerly. Up to ten or fifteen years ago the concensus of opinion was that fasciation was an individual phenomenon and that its appearance depended entirely on external conditions. But a more careful study of the phenomena and especially the observations of de Vries * have shown that fasciation is a character which may be inherited, though to a varying degree. In some individuals it may seem to have disappeared, but only to reappear in their descendants. The latent condition of the character is also shown by trees which for some years produce fasciated branches and then normal ones, to be again followed by fasciated limbs. It has been shown by de Vries that in such cases the manifestation of fasciation is due to favorable external conditions. Unfavorable conditions have a tendency to prevent it. At Berkeley, plants of *Rhus diversiloba*, the poison oak, which had shown fasciation in the growth of three successive years, ceased to produce fasciations after being transplanted. Numerous similar instances might be quoted. As Goebel † points out and de Vries ‡ again recalls, wherever external influences cause the appearance of fasciations or anomalous structures in general the tendency to this must be present in a latent condition. If this tendency is absent all efforts to bring these structures about are futile.

That the fasciated character may remain dormant is well

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* deVries, Hugo. Die Mutationstheorie. **2 : 541.** Leipzig. 1901–1903. — Here other references will be found.

† Goebel K. Organographie der Pflanzen. **1 : 158.** Jena. 1898.

‡ *Loc. cit.* 551.

shown by our *Oxalis* tubers. Morphologically normal tubers, when planted, produced, in some cases at least, fasciated stems. Still another instance is yielded by the tuber illustrated in pl. 17, f. 2, which has the following history: — The plants, after having been photographed, were laid away on a shelf, tubers and all. Three months later, one of the tubers, slightly fasciated, was found to have sprouted and to have produced two stems, the one normal, the other fasciated. Artificial conditions, such as nutrition, irrigation, or the cutting away of parts were here entirely excluded. Yet the character is present, in the one case in an active, in the other, probably, in a latent condition.

Though it is well known that the members of some groups seem to have a greater tendency to fasciate than others, this tendency must occur very generally through the plant kingdom. Both Monocotyledons (*Asphodeline*, *Lilium*, *Asparagus* etc.) and Dicotyledons (*Verbascum*, *Acacia*, *Rosa*, *Sisymbrium* etc.), though the former to a lesser extent, yield numerous instances. But is this tendency present in all members of the plant world? De Vries* believes it not necessary to assume this. "Allerdings scheint die Anlage zu Verbänderungen im Pflanzenreich aüsserst allgemein verbreitet zu sein, doch wohl nicht so allgemein, dass sie nicht gewissen Gruppen fehlen könnte." Time and experiment will have to decide. Various methods are now known by which fasciation may be brought about. Heavy manuring may cause normal descendants of fasciated plants to fasciate (*Crepis biennis fasciata*).† The stems of biennials with a tendency to fasciation, if produced in the first year are mostly normal. But if they are produced during the second year, fine fasciated specimens are ordinarily the result (*Aster Tripolium*,

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* *loc. cit.* 551.

† de Vries, H. *loc. cit.* 561.

Picris hieracioides etc.*) The time of sowing also seems to be of great influence. Goebel † calls attention to the fact that by leading the sap rapidly and with great intensity to a lateral bud, which ordinarily contains but little sap, fasciation may be produced. Thus he explains the frequent occurrence of fasciation in suckers and water-sprouts. Similarly, fasciation may be produced in annuals (*Phaseolus multiflorus*, *Vicia faba*) by cutting off the main stem directly above the cotyledons. Lopriore ‡ was able to produce root fasciation both by cutting off and by splitting the root tip, but did not succeed in producing it by subjecting roots to prolonged pressure. On the other hand, Sorauer § quotes an instance of a stem of *Tecoma radicans* which had become fasciated through appression to a wall, and of which the parts reaching above the wall likewise showed fasciation.

Experiments, mainly carried on at the Missouri Botanical Garden, have shown that at or just previous to the flowering period, plants, especially those with an indeterminate inflorescence, may be caused to fasciate by the use of the following method:—About the time of the appearance of the first flower the plant is kept as dry as possible, only enough water being given to prevent wilting. As a result the flowering period will be comparatively short, and, in an indeterminate inflorescence, the buds near the end of the spike remain undeveloped. If at this time the plants are daily abundantly irrigated, occasionally with manure-water, numerous fasciations will make their appearance. But it must be remembered that this result is usually reached only with plants which throughout their existence have

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* *Ibid.* 549.

† Goebel, K. *loc. cit.* 164.

‡ Lopriore, G. I caratteri anatomici delle radici nastriformi. Rome. 1902.

§ Sorauer, P. Handbuch der Pflanzenkranheiten. 1: 334. Berlin. 1906.

been well nourished and well cared for generally. For no apparent reason one plant will fasciate, while the next one, belonging to the same species, remains normal. This, however, affects in no way the value of the experiment, since this is undertaken only with a view to determining whether in any species fasciations can be produced. During 1905 fasciations were obtained by this method in *Antirrhinum majus*, *Actinomeris squarrosa*, *Solanum Lycopersicum* "Magnus," *Lythrum virgatum*, *Oenothera Lamarckiana* and *Collomia grandiflora*. Experiments with *Solanum Pseudo-capsicum*, *Capsicum annuum*, *Solanum nigrum* and *Abutilon Avicennae* yielded no fasciations.

It would seem that the cause of fasciation must be ascribed to the rapid introduction of sap into buds which would not normally produce them, as is suggested by Goebel. This is further borne out by observations on numerous plants, both cultivated and wild, growing at Berkeley, California. It was noted that within a week after a heavy rainfall at an unusual time (September, 1904), an abnormally large number of teratological cases were to be met with. They were not limited to fasciations, though these were most frequent, but included torsions, petalody of the stamens and phyllody of the pistil, frondiparous diaphysis — the prolongation of the axis through the center of the flower when the prolongation bears the character of a leafy shoot,* and fasciculations. One of the most interesting cases of the latter was met with in *Picris echioides* which showed also a slight chlorosis of the flowers, which were stalked. Contrary to expectation, prolification, *i. e.*, the production of secondary heads, which so often goes hand in hand with this phenomenon, was not observed.

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* This may be frequently observed in the peloric variety of *Digitalis purpurea*.

Among the most familiar instances of fasciation is that of the Asparagus. Interesting in this connection is the experience of an asparagus grower of California, who claims that the greater percentage of fasciated asparagus shoots is to be met with among those which are the first to pierce the soil, and especially so after a cold winter. This again would tend to confirm Goebel's view.

EXPLANATION OF PLATES.

Plate 17. — *Oxalis crenata*. Above, normal tubers, $\times 1/2$. Below, fasciated tuber bearing a normal and fasciated shoot; two views, slightly reduced.

Plate 18. — *Oxalis crenata*. A fasciated plant, $\times 1/6$.

Plate 19. — *Oxalis crenata*. Three fasciated shoots, one of them, bearing a number of aerial tubers, $\times 1/4$, the other two $\times 1/8$.

OXALIS CRENATA.

OXALIS CRENATA.

OXALIS CRENATA.

CONSTRICTION OF TWIGS BY THE BAG WORM AND INCIDENT EVIDENCE OF GROWTH PRESSURE.*

BY HERMANN VON SCHRENK.

INTRODUCTION.

For a number of years many branches of arbor vitae (*Thuja occidentalis*) in the Missouri Botanical Garden showed signs of disease and gradual dying from the tips of the branches inward. A careful examination of the twigs showed a condition represented on plate 20, figs. 1, 2 and 3. At a short distance from the end of the twig a swelling was usually found, which in the case of twigs which were still comparatively green was very small, but in many cases reached a size of four and five times the diameter of the twig below the swelling. The part of the branch above the swelling was usually very much larger in diameter than the branch below the swelling. Where the swelling was at all large the parts of the branch towards the outside of the tree were usually found either in a dead or dying condition. In every case the diseased branches showed marked tendencies towards the formation of secondary buds and branches, so that frequently the tip of a branch had the appearance of a small broom (pl. 20, fig. 3). After looking at a number of trees the swelling was finally found to be due to the girdling action of the bands of the common bag worm (*Thyridopteryx ephemeraeformis* Haworth), (pl. 20, fig. 2). A great many instances of the swellings with the bag worm still in position were found in the vicinity of St. Louis and in other parts of the country; and in all of the older swellings where no bag was visible, the band of the worm was found still encircling the branch.

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* Published by permission of the Secretary of Agriculture. The main results here detailed were communicated to the Society for Plant Morphology and Physiology, at its Ann Arbor Meeting, in December, 1905.

There seems to be no doubt therefore that the band of the bag worm was responsible for the swellings, serving as a kind of ligature which prevented the passage of elaborated materials from the outer part of the branch towards the trunk, and acting just as a wire would when wound around a growing twig. In the course of time the part of the branch above the band increased in size until such time as the passage of the elaborated material was prevented entirely, resulting in the final death of the branch.

After attention had been called to the occurrence of the bags on arbor vitae and the girdling effect which they exerted, a search of the various trees in the Garden and in the country around St. Louis showed that this action of the bag worm on arbor vitae was an extremely common one; in fact it was almost impossible to find a tree of arbor vitae which did not show one or more of the swellings.

LIFE HISTORY OF THE BAG WORM.

In order to understand the manner in which the insect kills the branch it will be necessary to refer briefly to its life history. The common bag worm (*Thyridopteryx ephemeraeformis* Haworth*) hatches from eggs which have remained on the trees in the bags over winter. In the vicinity of St. Louis the larvae appear on shade trees in the early spring just as the buds are opening. The larvae feed on the young leaves, and very shortly after their appearance begin to spin small bags which they carry about with them. As the insect grows older practically nothing of the larva is visible except the anterior portion of its body, the rest of its body being encased in the bag. Towards the latter part of the summer, from the beginning of August on, the larvae attach the bag to some twig near the outer part of the tree; they do this by spinning a band

* For a good description of this insect and its habits, see Felt, E. P. Insects injurious to elm trees. (5th Annual Report, Fisheries, Game & Forest Commission of New York, p. 359, 1903).

around the branch in such manner that when the bag is finally fastened it is suspended from the branch, as shown in plate 21. The band varies in width and in thickness. It is closely adapted to any irregularity in the bark of the particular twig, and is so wound around the twig that it can be moved laterally only with difficulty. It is in no way pasted or glued to the bark, as can easily be shown by cutting the band at any point, which will cause the cocoon to drop. The insect will attach its bands, almost without fail, only on one-year-old twigs. Whether this is due to the fact that it is upon these twigs that it has been feeding, or whether it is due to the fact that these twigs are usually smallest, I have not been able to determine. That the size of the twig has something to do with the weaving of the band is shown by the following experiment: In order to test the strength of these bands, the writer desired to get bands of as great a length as possible. A number of the larvae which were found ready to attach themselves to twigs were taken and placed on twigs having a diameter of about three-eighths of an inch; in no case did these transplanted larvae weave a band around a twig of this size. When they found that they could not get away from the large twig they made a band which they glued to the lower side of the twig, thereby suspending the cocoon; when the branch was one-fourth inch thick or less they invariably made a band completely around the twig. The relation between the size of the twig and the number of bands is shown in detail in Table I. After the band has been woven, the cocoon hangs on the tree over winter and into the next spring, in fact until about the end of June of the following year. Some six weeks or more after the leaves have fully opened one can pass under trees which have been covered with the bag worms during the winter and find hundreds of them lying on the ground under the trees. The falling of the bags is brought about by the bursting of the bands by the twigs as they increase in diameter. That

this is the cause of the bursting of the bands was determined repeatedly by noting that in no case would the bands burst until a considerable formation of wood took place in the twig to which the bags were attached. The bursting of the bands took place at almost any point in their circumference except at the point where the bag was attached to the band; in other words, the weakest point in the bands usually was at some point away from the bag itself. This was a fact of considerable interest, the force of which will be referred to again further on.

FORMATION OF THE SWELLINGS.

By the end of July practically all of the bands of the previous year have dropped from the trees; here and there however, one finds a bag which has not fallen. Upon examination it will be found that the band of this particular bag still passes intact around its twig; and should this bag remain upon the twig until September, one will find that a swelling, such as the ones referred to above, has begun to form. It would appear from this that any particular band which remains throughout the summer has been strong enough to resist the forces exerted by the growing twig as it expanded in the formation of new wood, and that the band then acted as a ligature. All of the conditions for the formation of the swelling were thereby brought about.

As the bag worm occurs on other trees besides the arbor vitae, an examination was made of trees in the Garden and in the streets of St. Louis for the purpose of finding out whether the girdling action noted for the arbor vitae trees also took place on other trees. After a few days of searching it was found that practically every tree species upon which the bag worm occurred was girdled now and then very much as were the arbor vitae trees. On some species the girdling action appeared to be very common, particularly on the sycamore and soft maple, but nowhere did it occur as frequently as with the arbor vitae. Thus

far the constrictions have been found on the following trees: soft maple, sycamore, willow, poplar, sassafras, red gum, white oak, locust, apple, cherry, hemlock, bald cypress, Virginia pine, Deodar cedar, larch, *Juniperus virginiana*, *Juniperus occidentalis*, *Thuja occidentalis*, and *Juniperus chinensis*. It is very probable that similar swellings will be found on other species of trees where the bag worm occurs.

The effect of the girdling action of the band differed very materially on different kinds of trees. Two types may be distinguished. In one case the band evidently has stopped the passage of plastic materials through the bark absolutely. As a result of this an accumulation of these substances has taken place on the outer side of the band and the cambium layer at this point has formed wood cells and bark cells to an enormous degree, as a result of which the outer part of the twig has grown very much in diameter, particularly so immediately beyond the band. The portion of the twig towards the tree has practically stopped growing entirely; cases of this kind are shown on pl. 20 and pl. 24.

In the second case the pressure exerted by the band was evidently not sufficient to entirely stop the passage of plastic materials, or only temporarily so. In this case, a slight swelling of the portion of the branch outside of the band will be formed after a month or so, following the beginning of wood development. At the end of the first year a condition such as is shown on pl. 22, fig. 1 is found. This represents a two-year-old maple twig. It will be noted that the outer part of the twig is somewhat larger than the part towards the trunk, but that there is also a considerable increase in diameter of the twig on the side of the band towards the trunk; this is shown likewise for the willow, oak, red gum, sycamore, etc. (pl. 23). After another year's growth a still further increase in the diameter of the outer part of the twig has taken place (pl. 22, fig. 3), but the inner portion of the twig, towards the trunk, has like-

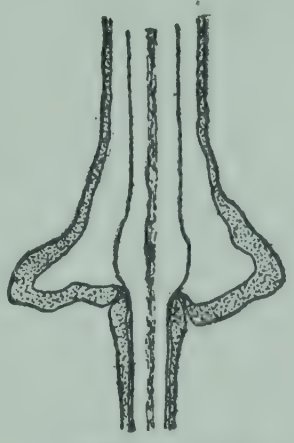
wise increased in diameter. Two distinct flat surfaces are thus formed where the swellings above and below the band face one another. In the course of time, in certain cases, two years after the band has been on the twig, these two surfaces unite completely around the twig (pl. 22, fig. 2), and there is to all intents and purposes a union between the two swellings which resembles in many respects the union which takes place between two pieces of callous tissue after they meet from opposite sides of a wound. After the two surfaces have united, the development of the branch goes on as if there had been no girdling; and the band of the bag worm is enclosed within the swelling and may remain there for an indefinite period. Plate 22, fig. 4 shows a branch of a maple tree ten years old. There are no signs visible on the outside, of any disturbance due to the insect except the old cocoon, which is still hanging from the lower side of the branch, with not only the slender filament, but also a large portion of the upper part of the cocoon enveloped by the wood of the maple. In the case of the sycamore, maple and other rapidly growing trees the disturbance caused by the bag worm is generally only a temporary one, and in the many hundred cases found on these trees, there is not one instance where death followed the failure of a twig to break the band.

The formation of the single swelling on the outside of the band is confined singularly enough almost wholly to the coniferous trees, in some of which it is extremely striking. The most remarkable cases of excessive swelling with subsequent death were found on a young tree of the Deodar cedar on the grounds of Tulane University, in New Orleans (pl. 24, fig. 5, 7, 8). A similar large swelling was found on a tree of *Pinus virginiana* growing near Washington, D. C. (pl. 24, fig. 1). The only case of this kind among dicotyledonous trees was found in the locust (*Robinia pseudacacia*). Four trees of this species were found in a park in New York City with some ten swellings;

of these one is shown on plate 23, fig. 2. In every case the outer part of the branch was dead, and no growth had taken place in the twig between the constriction and the tree. The marked inability of the conifers to adapt themselves to these unusual circumstances is very striking.

STRUCTURAL CHANGES CAUSED BY THE BANDS.

The changes which take place in the branch of a tree as a result of the pressure exerted by the bands of the bag worm are of two distinct types, one of which may be illustrated by the arbor vitae and the other by the maple or sycamore. In the arbor vitae and other conifers, growth starts under the band in June following the year in which the band is attached to the tree. Where the expanding force of the tree is great enough to burst the band, or where the band is weak, no change takes place which differs in any way from the normal development of the particular twig. Where the band happens to be a strong one which cannot be burst by the growing twig, changes of a very radical nature make their appearance a month or more after the beginning of the growth period of the twig. A longitudinal section made through such a twig after a year's growth of the arbor vitae is shown in fig. 1. It will be noted that the cambium layer formed a number of rows of wood cells immediately under the band, but that after a very brief period the formation of wood in the twig, beginning at the band and below it, stopped entirely, while the part towards the outside of the band continued to grow vigorously, producing the peculiar swelling above referred to. The most striking change in the immediate vicinity of the band consists in the enormous development of bark. Immediately above and below the constriction the bark is two or three times as thick as it is normally (fig. 1). The wood cells formed immediately

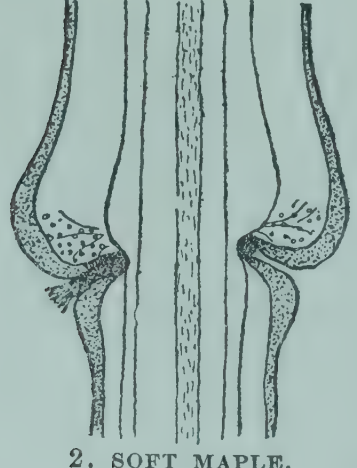


1. ARBOR VITAE.

beyond the constriction continue to grow normally. The new wood formed above the band differs but little from the normal type; the tracheids are somewhat shorter than the normal ones, but the chief difference lies in their manner of arrangement, for a complete turning takes place in their position. Instead of growing longitudinally they grow at right angles to the long axis of the twig. In other words, in the region of the swelling all wood fibers formed during the first year under the constriction extend around the twig instead of longitudinally. In the arbor vitae the normal direction of the wood fiber is rarely re-established except in such twigs as are growing vigorously, because before a resumption of normal growth is possible the twigs usually die. Where the development of the swelling is very large, a decided buckling of the cells of the bark frequently takes place.

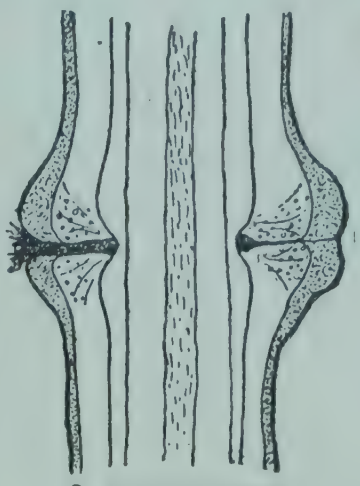
An examination made of a two-year-old constriction in the latter part of the summer, shows the presence of very large amounts of starch in the bark, medullary rays and pith ring in the part above the constriction, while there is practically none in the part below it. An inch or more below the constriction no starch whatever occurs.

The changes which take place in hardwoods differ very materially from those just described for the arbor vitae. In the spring or early summer following the constriction, both the wood and bark continue to form under the band, both above and below it. Figure 2 represents an early stage in a maple constriction. After a month or more the wood cells appear as if constricted immediately under the band. A diversion of the wood cells from their normal longitudinal direction to one at right angles takes place in the sycamore, maple and other hard woods very much as it

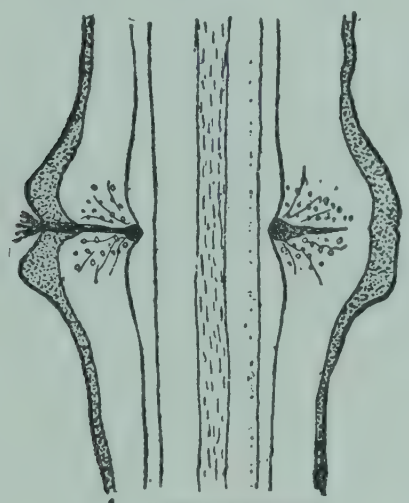


2. SOFT MAPLE.

does in the arbor vitæ, but it occurs on both sides of the band. As a result of the growth both above and below the band, two lips or rings of tissue are formed (fig.2–4). which at first are separated, but which soon meet above the band and become closely appressed (fig 3). At the end of the first year the two lips have usually joined, and a continuous ring of wood fiber has once more been formed. As soon as the union has taken place between the two lips the wood fibers once more assume their normal longitudinal position (fig. 4).



3. SOFT MAPLE.



4. SOFT MAPLE.

The parts immediately above and below the band show an abundant supply of starch throughout the summer and late into the fall, from which it is evident that the flow of nutrient substances from the outer part of the twig to the lower part is never entirely stopped by the constriction.

The wood cells formed under the band during the process of healing differ considerably from the normal wood tissue. The first wood cells formed under the band in June, following the year when the band is first attached to the twig, are normal in every respect. Although the band is fastened firmly around the twig, it is probable that it at first exerts very little pressure upon the growing cambium cells; it is probable likewise, that the band stretches to some extent during the first month or two following the beginning of the growth period of the twig. At a certain point, however, a time is reached where the band no longer stretches,

and from then on the band exerts an increasing amount of pressure upon the underlying cambium cells. A word should be said at this point as to the structure of the band. It is composed of a series of fine strands of silk which are densely interwoven, forming a very compact mass; the individual fibers appear to be pasted together with a cementing material; they are closely adapted to the irregularities of the bark, so that the pressure which the band as a whole exerts is a very even and regular one.

After the pressure has begun to act a marked change in the character of the wood cells formed under the band is noticeable, which gradually becomes more marked as the amount of wood formed below the band increases. After about six weeks all further formation of wood tissue under the band ceases. On plate 25 are shown sections of normal maple wood (fig. 1) and of a portion of the wood formed under a band in a maple twig (fig. 2); likewise sections of wood of the red gum from normal (fig. 3) and constricted regions (fig. 4); and plate 26, figs. 1 and 2, shows two photomicrographs of a cross section of maple and red gum twigs immediately under the band. It will be noted that as the pressure increases the number of vessels decreases proportionately, and at a period when the growth has almost ceased, the formation of vessels has almost stopped. Under the increased pressure the wood cells take on an entirely different appearance; instead of the comparatively thin-walled, large-lumened tracheids, one finds thick-walled, very small-lumened tracheids forming, which continue to be formed up to the very time when all growth ceases. The vessels which form at the period of greatest pressure show a tendency to become round and thick-walled, as well as smaller in diameter. The medullary rays show a decided tendency to buckling. Instead of growing out in a straight line radially, they bend towards one side or the other as if pulled laterally. This bending is more striking in some instances than others. It is of

further interest to note that the very last wood cells formed before all growth ceases still have all the characteristics of wood fiber; they are smaller, to be sure, but there is no mistaking them for anything but typical wood cells. Immediately between the last wood cells formed and the band, will be found the very much compressed and shriveled remnants of the original bark, which in the majority of cases has been so thoroughly compressed that it appears as a dark, opaque line, in which no structure can be discerned.

The influence which pressure has upon the development of wood tissue was first investigated by Sachs (8) and DeVries (9). Sachs, in an attempt to explain the cause of the formation of spring and fall wood in trees, assumed that the cambium is acted upon by a definite pressure exerted by the bark, and that this pressure increases from the spring to the fall, equalizing itself during the winter; he took the formation of cracks in the bark in the spring as an evidence of the growth energy of the woody cylinder overcoming the bark pressure acting against it. DeVries, in an endeavor to explain the causes of spring and fall wood, made a series of slits in the bark in the fall, as a result of which he noted the formation of spring wood. This he explains by imagining that the bark pressure was destroyed because of his making slits, and consequently large-lumened cells were formed. He likewise placed a number of ligatures on branches in the spring and observed the formation of summer wood under these ligatures. He concludes from these experiments that the radial diameter of the wood elements is determined by the bark pressure exerted during their formation; and furthermore that the number and size of the vessels in any one wood ring are determined by the bark pressure which happens to be experienced at the time of formation of this particular ring, higher pressures resulting in fewer vessels which are of smaller diameter.

Krabbe (5) disagrees with both Sachs and DeVries as to the existence of bark pressure. In a series of extensive experiments he shows that the difference in the bark pressure during the spring and summer is so small that it could not possibly account for the difference in structure of spring and summer wood. In another series of experiments Krabbe (6) increased the bark pressure by means of wooden cylinders formed into a chain, to which weights were attached; by increasing the pressure on the growing tree he found that one can increase the bark pressure two or three times without influencing the growth in thickness of the branch. For conifers he found that a pressure of from three to five atmospheres slowed up the growth and changed the radial diameter of the cells, while a pressure of ten atmospheres stopped the growth entirely. For broad-leaved trees he found that a pressure of from five to seven atmospheres reduces growth; but he failed to determine the upper limit of growth. In discussing the morphological changes which the wood cells undergo as the pressure increases, he notes in particular a reduction in the number of cells formed as the pressure increases, and the gradual change of the vessels from an elliptical cross-section to circular. Another point which he notes is that the cambial cells continued to form wood cells of a normal character, irrespective of any pressure which he was able to bring to bear upon them. The newly formed wood cells, which under ordinary circumstances are capable of expanding until they reach a size very much larger than when first formed, are materially influenced by the pressure, and as the pressure increases, the stretching of the newly formed wood cells may cease altogether, thereby giving rise to a much smaller lumen than is normally the case. Although Krabbe states nothing as to the shifting of the medullary rays, he shows (in two figures) a shifting similar to that found in the

sycamore and maple under the pressure of the bag worm bands.

Küster (7), in an investigation on the union of apposed branches, states that the first effect of the mutual pressure of two such organs, aside from the changed direction of the medullary rays, consists in a flattening of the surfaces apposed, due to growth reduction. An increased growth of the primary bark at the edges takes place. He does not agree with Krabbe as to the activity of the cambium, finding that the growth of the cambium does not remain normal up to the point of union, but that growth stops entirely, because of too great pressure. Before it stops growing, Küster finds that the cambium forms a more or less well developed layer of modified woody tissue, which Krabbe does not mention at all. This modified layer of woody tissue differs from the normal wood in that it is composed of parenchymatous cells, and is to be considered as a parenchymatous tissue. It consists of libriform vessels and parenchymatous cells, which are more or less thickened, pitted and lignified. For the sycamore, Küster states that "it is surprising to see the extraordinary development under the influence of pressure; parenchymatous tissue develops, which starts sharply defined from the normal wood. Outside of this normal wood one finds a thick layer of radially elongated, lignified and very much pitted parenchymatous cells. True wood cells continue to be formed only here and there, and in a cross-section the groups of these wood cells enter into the parenchymatous mass in a wedgelike manner. Finally the formation of even these isolated groups of wood cells stops entirely. . . The pressure is not the physical cause of this growth, but acts only as a stimulus which affects the protoplasm, and the real cause must be sought in the nature of the latter itself." Küster discusses the apparent discrepancy of his own and Krabbe's results, and sees an explanation in the different manner in which the pressure was applied; in

one case with rollers acting for a short period and rapidly applied, while in the case of Küster's unions it started as a slight pressure and, increasing to a maximum, continued for a long period of years until a pressure of 11-17 atmospheres was reached. Küster furthermore calls attention to the change in direction of growth of the cambial cells, which normally form woody cells with their long axes parallel to the axis of the stem, but which under the influence of the pressure change their direction 90 degrees, many of them being curved and bent into "C" and "S" forms. He regards these as originating from bent and displaced cambial cells; their formation being a physical process, and their displacement probably due to the pressure coming only from one side, which gives these cells an opportunity for lateral development.

In the case of the bands of the bag worm, the pressure applied was very similar to that obtained in the investigations of Krabbe, with the exception that the force was applied gradually, and in that manner was more like the pressure obtained by Küster when he caused two branches to join by being pressed together at one side. From the description of the changes which take place in hardwood trees particularly, under the influence of the constriction caused by the bands of the bag worm, it will be noted that these changes are almost identical with those described by Krabbe. In no case is there any evidence of the formation of the parenchymatous tissue spoken of by Küster. Examination of branches of maple, sycamore, red gum, willow, and other hardwoods, showed that in every case, in spite of the enormous pressures that were exerted by the band towards the latter part of the growing season, there was no cessation on the part of the cambium in the formation of typical wood cells, though the last cells formed were very much smaller, just as were those found by Krabbe under his rollers (pl. 25 and 26). I am inclined to agree with Krabbe that the pressure does not in any

way influence the division of the mother cells of the cambium, but that any change which takes place occurs after the wood cells have been formed. The cambial cells divide even under great pressure, though when the pressure reaches a certain point it is probable that the rate of division is considerably reduced. The formation of new cells evidently stops abruptly; in other words, the conditions for the development of new cells from the cambium are such that the latter is able to form these new cells irrespective of the growing pressure up to a certain point, and when this point has been reached growth stops. The cambium appears to be more or less uninfluenced in the character of its cell divisions by pressure exerted upon it, and is able to continue its activity up to a maximum point.

Concerning the discrepancy between the findings of Küster and those of Krabbe and myself, I am inclined to ascribe the formation of the parenchymatous tissue in the branches investigated by Küster to the unequal pressure to which the apposed surfaces were exposed. I have found a tissue which resembles that described by Küster under similar conditions in stems of maple and other trees in the region immediately below twining vines, particularly where the latter caused a constriction in the bark of the trunk around which they were growing.

The change in direction of growth of the cambial cells resulting in a shifting of the axis of the wood cells to an angle of 90 degrees from that usually occupied by them, has already been referred to above.

Summing up the changes which occur in the region of wood under the band, it may be said that with an increase of pressure smaller and smaller cells are formed, because of the inability of the newly formed wood cells to expand to a normal size; the cambium continues forming wood cells of the usual kind but at a decreased rate as the pressure increases. Where the pressure is reduced, at the edges of the band, a shifting of the cambial cells takes place, result-

ing in the turning of the long axis of the wood fibres at an angle of 90 degrees to their usual position.

It has been stated that as soon as the pressure exerted by the band becomes great enough to retard the expansion of newly formed wood cells, an increased growth becomes evident above the band in conifers, and both above and below the band in hard woods. The cambial tissue in the region not acted upon by the pressure at first continues to grow normally, but very soon increases its rate of cell division. Under the changed condition of tension a change of direction of the cambial layer takes place; instead of remaining a sheet parallel to the long axis of the branch, the cambium both above and below the band is curved outward. The wood and bark cells produced, because of this altered position of the cambium, instead of growing in a radial direction, as they do normally, are turned so that their axes gradually approach a direction at an angle of 90 degrees from their normal position. With this changed position in the direction of growth of the wood and bark cells comes an increased development of both, so that after awhile the branch is very much thicker immediately above and below the band than it is at some distance from it. The swellings appear as the lips already referred to.

The tissue composing the two lips is, to all intents and purposes, wood tissue. The tracheids are normal in character, although many of them are somewhat shorter than those formed under normal conditions; there is, in other words, no development of what might be termed callous tissue or anything resembling the tissue known as "wound wood." The development of the lips, in many respects, however, resembles the development of callous tissue after a ring of bark has been removed from a twig. In the latter case, the stimulus, as a result of which an increased development of tissue takes place at the margins of the cut, consists in the interruption of the strains normally active in the growing region of the twig. By cutting away a certain

layer of bark the cambium is free to develop without the restraining pressure exercised by the bark, and as a result grows rapidly in the direction of the least strain. This growth continues until the callous surfaces formed on the upper and lower sides of the wound unite and re-establish the normal pressure conditions. In the case of the constrictions caused by the bands of the bag worm, a similar disturbance is brought about by arresting the development of the cambial layer for a certain distance completely around the twig, and thereby disturbing and probably rendering inactive the normal bark pressures. To all intents and purposes therefore the formation of the lips of the bag worm constrictions may be said to be due to a similar stimulus to that which results in callous formation after a wound, though the formation of the lips is not to be regarded as a callous development, but rather as a new type of healing of a different character.

It is a well-known fact that, where branches are girdled by removing a portion of the bark down to the woody cylinder, the development of callous tissue takes place from the upper or outer edge of the wound. The transfer of carbohydrates and nitrogenous substances takes place in a downward direction from the leaves towards the trunk (Czapek, 1 and 2). Some writers, *e. g.*, Fischer (3), have gone so far as to maintain that the carbohydrates formed in the leaves go downward only in the bark, and that in girdled branches they cannot even be transferred across the wound through the pith or wood parenchyma. Although very little attention has been paid to the problem of nutrition in the healing of the disturbance caused by the bands of the bag worm, it is nevertheless suggestive to note the difference in the manner of healing between the coniferous and hardwood trees. As soon as the pressure exerted by the bands becomes great enough to obstruct the cells of the bark, an evident congestion takes place in the region above the band. In the coniferous trees the food supply is evi-

dently entirely cut off, and as a result practically no growth takes place in the twig on the side below the bands. The portion of the twig above the band continues to grow for a considerable period. The absolute cessation of the passage of starch and other substances from the leaves towards the trunk is well shown by the total absence of starch in the region below the band in the fall of the year, while in the region above the band the wood parenchyma and bark cells are completely filled with starch. In the hardwood trees the pressure of the band is evidently never great enough to entirely obstruct the passage of elaborated materials. No cases were found in the large number examined, with the exception of the locust, where the constriction caused by the band was great enough to prevent the growth of the part below it. In the fall of the year starch is found in the parenchymatous tissue both above and below the band in almost equal quantity. The difference in the behavior of the conifers and the hard woods is a suggestive one, as indicating the greater adaptability of the latter, and their higher grade of physiological organization.

GROWTH ENERGY OF TWIGS AS INDICATED BY THE PRESSURE OF THE BANDS.

It has been stated that in the normal course of events the twigs burst the bands of the bag worm shortly after the beginning of the period of wood formation in the early summer of the second year. Now and then the strength of a band was such, however, that the twig failed to burst it, and as a result the constrictions just described were formed. The bursting of the bands has been explained as due to the force exerted by the twig after it began to grow in diameter. Putting it in another way, the bursting of the band may be said to be due to the growth energy developed by the growing twig. That plants do exert a certain amount of growth energy is a familiar fact. It is well known how the roots of trees will lift the flagstones in the

streets of our cities; the lifting and pushing power of roots and trunks is furthermore frequently noted in the forest, where large boulders are pushed aside or lifted. Another familiar instance of the energy exerted by the growth of plant tissue is found in the roots of most higher plants, which exert a certain amount of energy in pushing aside soil particles. Although this growth energy may sometimes be very large, it frequently is not sufficient to overcome the obstacles to which growing parts are subjected. This is frequently illustrated by roots which grow in the clefts of large boulders — they are frequently unable to burst these, and as a result, are forced into a flattened form. Many climbers exert a sufficient pressure upon the trunks around which they are growing to arrest development. Wires and other bandages frequently bring about girdling of trees very similar to those described for the bag worm.

While it has been realized that the amount of energy exerted by growing tissues may sometimes be very large, very little is as yet known as to how large the amount of energy developed by growing tissue actually is. In the course of the investigation on the constrictions caused by the bag worm bands, it was suggested that these bands might serve to indicate something as to the extent of the growth energy of young twigs. In the largest per cent of the cases the twigs burst the bands; they must therefore exert a radial pressure outward greater than that usually exerted by the band in an opposite direction. A series of experiments was therefore undertaken to determine how great the pressures were which the bands exerted upon the twigs, with the object of using the results as a guide to determine the growth energy of the twig.

Of the investigations hitherto made to determine the extent of the growth energy of plant tissues, there is practically only one which needs consideration. Krabbe (6) undertook some years ago to determine the extent of the growth energy of various trees, by placing bands, consist-

ing of a series of rollers, on the growing branches, and causing these bands to press with varying loads upon the branch, by attaching weights. For the details of Krabbe's method, the reader is referred to his original paper. Krabbe placed different weights on different branches, and after having left them for a season, he made microscopic examinations of the tissues immediately under the band. He attempted by so doing to find what weight, or in other words, what radial pressure, would stop the increase in diameter of the branch. He holds that this weight would be equivalent to the growth energy of the twig.

As a result of his investigations Krabbe concludes that the growth energy of the cambium ring and young wood cells in coniferous trees is at least 10 atmospheres. For hard woods he finds that the growth energy is at least 15 atmospheres. Krabbe was unable to determine the exact value of the expansive force of the limbs and branches with which he experimented. His results simply show that with the greatest pressures exerted by his rollers, viz: 10 atmospheres for conifers and 15 atmospheres for broad-leaved trees, growth still took place under the bands. The figures which Krabbe obtained are to-day in general acceptance as probably representing the approximate minimum growth energy of branches. Friedrich (4) makes the statement that "the increase in diameter of the tree trunk takes place with a development of energy equal to at least 10 atmospheres."

In order to arrive at some conclusion as to the amount of energy required to burst the bands of the bag worm, it was necessary to determine, first of all, the pressure which the bands were capable of exerting radially. The radial pressure exerted by a band placed around a cylinder is determined by the formula

$$P = \frac{S}{r \times w},$$

in which P equals the radial pressure exerted by the band

per square mm. of surface, S equals the strain which the band is capable of exerting tangentially; or, in other words, the strength of the band which resists tearing, r equals the radius of the twig around which the band is fastened, and w equals the width of the band. A number of microscopic examinations were made to determine the variability of thickness in the band, which ought to be included as a factor in the above formula. The variation was found to be so small, however, that for the purpose of the experiment the thickness was left out of consideration. Several hundred twigs from which bag worms were suspended were collected in the spring of the year from shade trees in and near the Missouri Botanical Garden. The tree upon which the bag worm is most commonly found in St. Louis is the soft maple, and the bags found on this tree were made the chief subject of study. Another reason for so doing was that the bands found on the maple twigs were usually of a sufficient size to permit being measured, while those on other trees, and particularly on the conifers, were usually so small that with the apparatus at hand it was impossible to make exact determinations. The method which was used to determine the strength of the bands was as follows: With a sharp knife the bands were cut as near to their union with the bag as possible; the bag with the band was then removed from the twig without difficulty, and a second cut was made in such manner that the band was separated entirely from the bag. A flat sheet was thus obtained, varying from 6 to 12 mm. in length. After the band had been thus removed, a careful measurement was made of its width and of the diameter of the twig from which it was taken. After numerous trials, an apparatus was constructed consisting of a framework, from the top of which a pair of pliers was suspended, with the jaws pointing downward; a similar pair of pliers with the jaws pointing upward was arranged so that a scale pan was attached to its handles. In both cases the pliers were so

arranged that when a pull was exerted on the lower pair the handles of both pliers became more and more firmly compressed, thereby increasing their hold upon the bands placed between the jaws. When ready for the test the bands were carefully straightened, and the ends were placed between the jaws of the two pliers; only enough of the band being caught by the pliers to give a firm hold. Very fine shot was then gradually put into the scale pan attached to the lower pair of pliers until the band broke; the weight of the shot, plus that of the pan and lower pair of pliers, constituted the breaking weight of the bands.

It was at first thought that the weakest point in the bands would be where the bands were fastened to the bag; in order to determine whether this was the case, a number of tests were made by attaching weights to the bags themselves, and increasing the weights until something gave way. In every one of the preliminary tests the break in the band occurred at some point away from the bag attachment. In other words, it appeared that the weakest part of the band was not at or near the bag attachment. It was therefore considered to be perfectly fair to cut away the bag and to enclose the ends of the bands between the jaws of the pliers; the results obtained by breaking hundreds of the bands bore out these preliminary conclusions. It was found that in almost all cases the bands broke at some point between the jaws of the two pairs of pliers and not immediately at the edge of the jaws. It was furthermore noted that under most conditions where the bags were attached to twigs on the growing tree the break in the band occurred in a similar manner to that found when weights were attached to the bags themselves. An examination of a large number of bands made during June showed that with the increase in diameter of the twigs which brought about the bursting of the bands on the trees, the bursting of the band took place at a point away from the bag insertion.

The results obtained were calculated according to the formula given above; and, following Krabbe's method, the final figures were calculated to show the pressures in grams per square millimeter of bark surface, which were then reduced to atmospheres of pressure. For this purpose 10 grams were used as equivalent to 1 atmosphere of pressure per square millimeter. In the case of the maple some 400 bands were tested. It is proposed to test a great many more bands in the future in order to have a larger number of figures to work with.

Before drawing any conclusions as to the results of the strength tests, it should be stated that the use of the bands as an indication of the amount of growth energy exerted by the twig must be taken with some caution. No claim is made that the results to be discussed are in any way absolute; the bands are an extremely variable quantity; they differ in width and thickness, and the error in measurement is consequently to be considered. It was furthermore suggested that there might be a very decided difference in the strength of the bands, depending upon whether they were wet or dry, and likewise upon their age. The former point was considered of great importance, and accordingly a large number of bands were broken after they had been soaked in water for five days. It was thought possible that as a result of wetting during rains in the early summer, the bands might be considerably weakened, and that it would be at such a time that they were burst by the twigs. The results obtained from the tests with soaked bands in no way differed, however, from those obtained with dry bands, and it is accordingly the belief that the soaking practically does not weaken the bands at all, or at least very little. Concerning the effect of age, most of the bands were taken and tested during May and June, *i. e.*, after they had been exposed to the weathering influences during the fall and winter. It is therefore be-

lieved that if the weather exposure weakens them, they were tested at the time when they were weakest.

The first analysis of the measurements made deals with the size of the bands and their relation to the size of the twigs to which they were attached. It has already been stated that attempts were made to cause the insects to weave bands around large twigs, but in every case the insect refused to do so. On Table I the bands taken from

RELATION OF DIAMETER OF MAPLE TWIGS TO WIDTH OF BAND.

Width of Band. mm.	Diam. of Twig. mm.	1.5	2	2.5	3	3.5	4	4.5	5	5.5	Total Bands of one width.
1			3	2	1	6	2				14
1.5				2	13	6	2				23
2		1	11	22	46	16	12	3	2	1	114
2.5			4	16	28	12	5				65
3		1	11	22	52	16	13	5	1	1	122
3.5		1	4	4	11	6	3	1			30
4			4	5	10	1	5	1	1	1	28
4.5				1		2					3
5				2	4		1		1		8
5.5									1		1
6					1						1
6.5											0
7					2						2
7.5			1								1
8					1						1
Total bands per twig		3	38	76	169	65	43	10	6	3	413

TABLE I.

maple twigs are arranged according to their width and according to the diameter of the twigs. It will be noted that the largest number of bands occurred on twigs 3 mm. in diameter, and that there is a regular falling off towards both sides; in other words, the insect seems to select twigs having a diameter of about 3 mm.

Concerning the width of the bands, there is more variation. Of the 413 bands, 122 were 3 mm. in width, 65 were 2.5 mm. and 114 were 2 mm., in decreasing numbers of smaller and greater widths. The largest number occurring on any particular diameter of twig were 3 mm. in width. Preference for the twigs 3 mm. in diameter is furthermore shown on Diagram 2, a, representing the relation of strength, using the twigs of different widths as the variable, and Diagram 2, b, where the bands of different widths are used as the variable. The final results obtained with bands taken from maple twigs are plotted in Diagram 1; the figures at the bottom of the table indicate the number of atmospheres pressure exerted by any band upon the particular twig which it subtended. The figures at the left of the table represent the numbers of individual bands exerting any particular number of atmospheres pressure. There were, as may be seen from this, four bands which exerted a pressure of 10 atmospheres and 16 which exerted a pressure of 19 atmospheres each, etc. While the number of bands which were broken was a rather small one for the purpose of any definite statistical study, enough were tested, nevertheless, to show a number of interesting facts. The radial pressure exerted by the bands varied from 4 atmospheres to 162 atmospheres in the case of the maple. The greatest number of the bands varied between 14 and 44 atmospheres. The strength which some bands showed was surprising. On Table II a number of instances of extreme strength are shown for maple and other trees. The deductions which may be made in a tentative way from the results shown in Diagram 1 are as follows: A great variation in the pressures exerted by the bands of the bag worm on the twigs of maple trees exists. Some of these pressures are very great, and it is probable that bands like those which showed pressures of 102 to 162 atmospheres are the ones which are responsible for the

constrictions described above. Remembering that most of the bands which occur on maple twigs are burst by the twig every year (only 1.5–2 per cent are not burst), it seems probable that the larger number of bands represented in this table would have been burst during the growing period. As many of these show that these bands exert radial pressures running up to 40 atmospheres and more, it seems

EXCEPTIONALLY STRONG BANDS.

Tree on which bags occurred.	Width of band. mm.	Diam. of twig. mm.	Total Breaking weight. grams.	Atmospheric pressure.
White Pine	1.5	1.5	935	83.1
	3	2	2275	75.8
	3	2	2472	82.4
	1	2	650	65.0
	2	1.5	1090	72.7
Maple	3	3	3202	71.1
	3	3	4324	96.8
	1	2	668	133.6
	2.5	3	3727	100.7
	3	2	3632	121.1
	.5	4	1620	162.0
Sycamore	3	2.5	1778	177.9
Willow	1.5	1.5	1217	108.1
	2.5	2.	3272	130.8
	3.5	3	4737	90.2
	2	1.5	1632	108.8
	2.5	1	1775	158.0
	2	2	2130	106.5
	1.5	1	900	120.0
	2	2	2350	117.0
	4	2	3675	91.9

TABLE II.

likely that the pressure which the twigs are capable of exerting radially must be at least equivalent to these pressures in order to burst the bands. It will be remembered that the figures which Krabbe obtained, showing that the pressure exerted by growing twigs of hard woods was 15 atmospheres or thereabouts, in no way indicated what the upper limit might be. Judging from the structure of the wood which he shows, cell division was still taking place

with considerable activity under the bands weighted so as to exert a pressure of 15 atmospheres, and Krabbe states distinctly that the growth energy must therefore be equivalent to *at least* 15 atmospheres. As a result of the few tests herein described, I am inclined to the belief that the pressures are probably very much higher than 15 atmospheres. Owing to the variability of the bands it does not seem practicable, particularly with the small number of bands tested and in the absence of determinations as to their thickness, to place any absolute value upon the growth energy as determined by the bands. That the growth energy exceeds 15 atmospheres seems very probable, and I am inclined to the belief that it may reach the extent of 30 to 40 atmospheres, and possibly more. As a matter of statistical interest, Diagram 2, a and b, is added. The upper diagram (a) shows the relation between the strength of bands of different width, and the lower one (b) the relation between the strength of bands found on twigs of different diameters. Both of these tables show that the bands of greatest strength are those that are attached to twigs of 3 mm. in diameter.

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EXPLANATION OF PLATES.

Plate 20. — Constrictions caused by the bands of the common bag worm (*Thyridopteryx ephemeraeformis* Haworth) on branches of arbor vitae (*Thuja occidentalis*). Natural size.

The two upper figures are living branches. The lowest one shows a branch killed by the band of the bag worm.

Plate 21. — The bag worm on living one-year-old branches, as it appears a month after the attachment of the bags, usually about the end of September. The upper figure shows it on a sycamore branch, the lower on a branch of the ash-leaved maple. Natural size.

Plate 22. — Constrictions caused by the bag worm on maple twigs of various ages. 1. Twig two years old showing early stage of constriction. 2. Twig 2 years old, showing beginning of union of two lips. 3. Twig 3 years old with healing almost complete. 4. Branch ten years old, healing complete, and top of bag partially overgrown by the wood. Natural size.

Plate 23. — Constrictions caused by the bag worm in various hardwood trees. 1. On willow. 2. On locust. 3. On sycamore. 4. On red gum. 5. On sassafras. 6. On poplar. 7. On white oak. 8. On apple. × ½.

Plate 24. — Constrictions caused by the bag worm on various coniferous trees. 1. On *Pinus virginiana*. 2. On *Thuja occidentalis*. 3. On bald cypress. 4. On larch. 5. On Deodar cedar. 6. On hemlock. 7, 8. On Deodar cedar. × ½.

Plate 25. — Cross sections showing structure of normal wood, and wood from the bag worm constrictions. 1. Normal wood of the soft maple. 2. Wood of the soft maple taken from a point immediately under

the band of the bag worm where growth had stopped entirely. 3. Normal wood of the red gum. 4. Wood of the red gum taken from a point immediately under the band of the bag worm where growth had stopped entirely. × 400.

Plate 26. — Photomicrographs showing the cross sections of wood taken at points immediately below the bands of the bagworm. The bands were situated at the top of both figures. Upper figure, from a maple constriction. Lower figure, from a red gum constriction. × 50.

DIAGRAMS.

Diagram 1. — Showing the number of atmospheres pressure exerted by the bands of the bag worm, and the frequency with which the various pressures are exerted among 413 bands. The abscissae show the number of atmospheres pressure; the ordinates indicate the number of individual bands exerting any given pressure.

Diagram 2. — a. The relation between the varying widths of bands and the strength of the bands, expressed in terms of number of atmospheres presssure. The abscissae represent the number of atmospheres; the ordinates the number of individuals. — b. The relation between the varying diameters of twigs and the strength of the bands found encircling them, expressed in terms of number of atmospheres pressure. The abscissae represent the number of atmospheres; the ordinates, the number of individuals.

TEXT FIGURES.

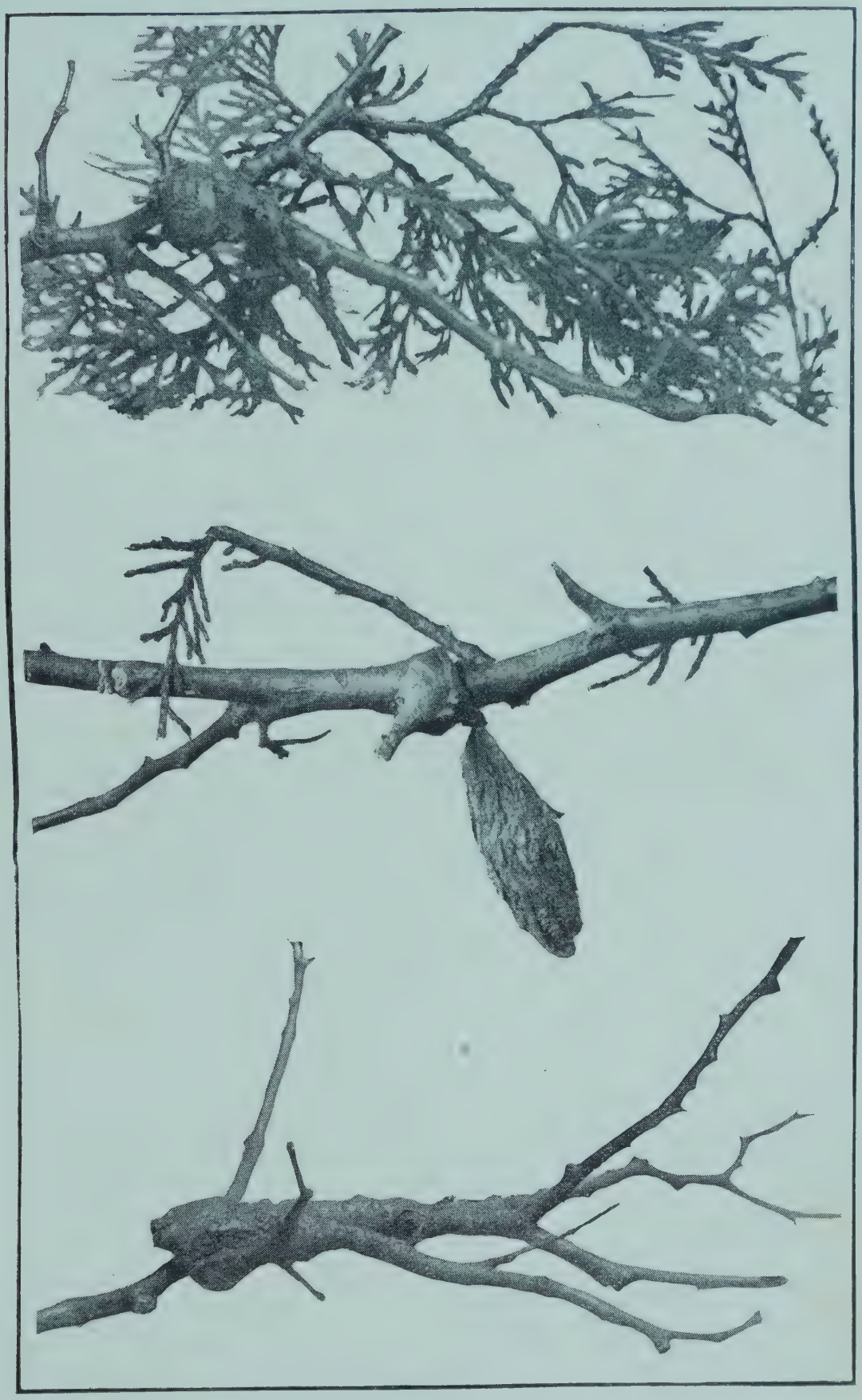
Figure 1. — Longitudinal section through an old swelling of the arbor vitae (*Thuja occidentalis*), showing how the upper or outer portion grew in diameter, while the part below the band stopped growing entirely. (P. 159).

Figures 2–4. — Longitudinal sections through constrictions of the soft maple, caused by the band of the bag worm. The figures show successive stages of healing. Figures 2 and 3 show the top of the bag at the left of the constriction. (P. 160, 161).

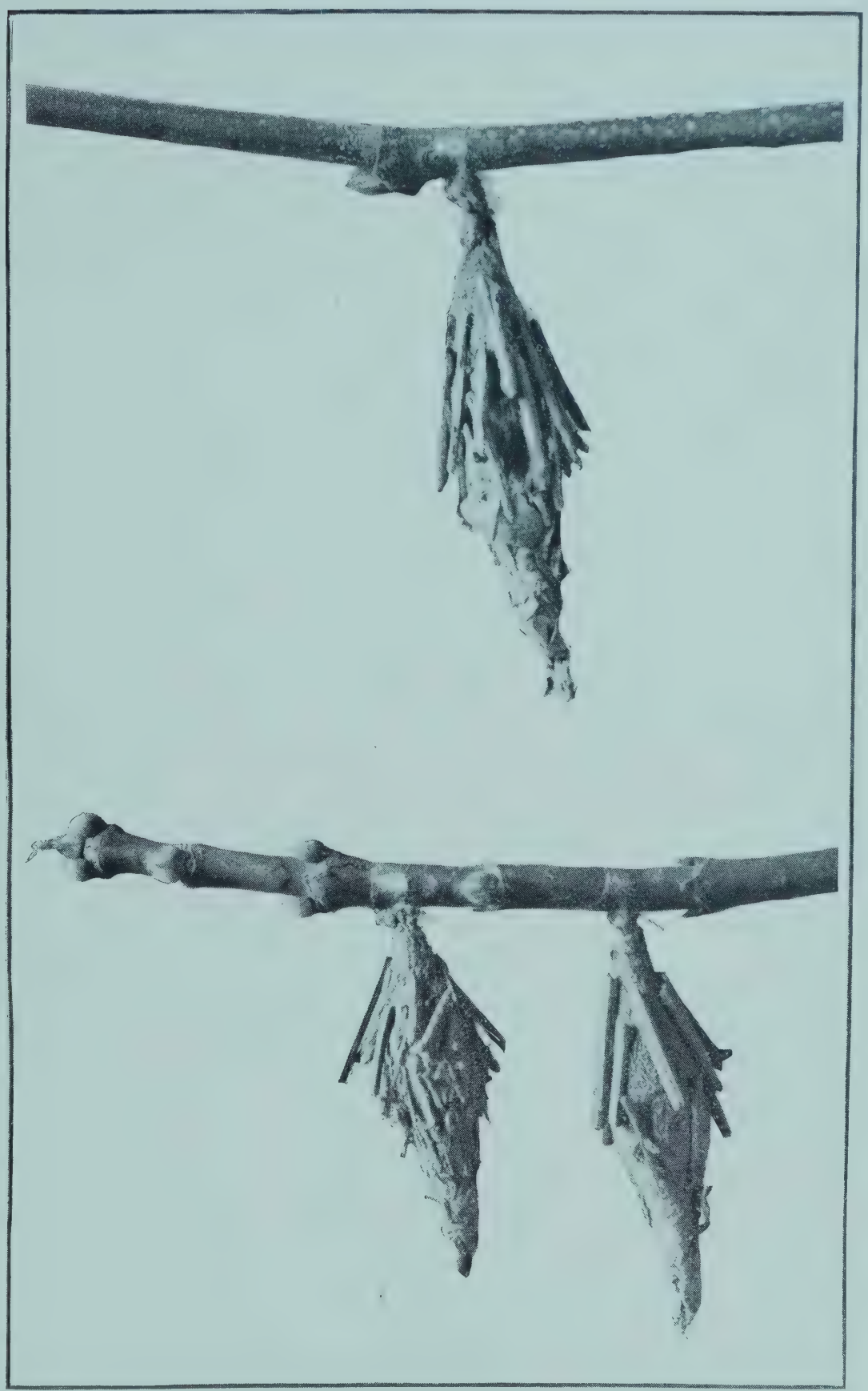
TEXT TABLES.

Table I.—Showing the relation of the diameter of maple twigs to the width of the bands of the bag worm which were found upon them. (P. 176).

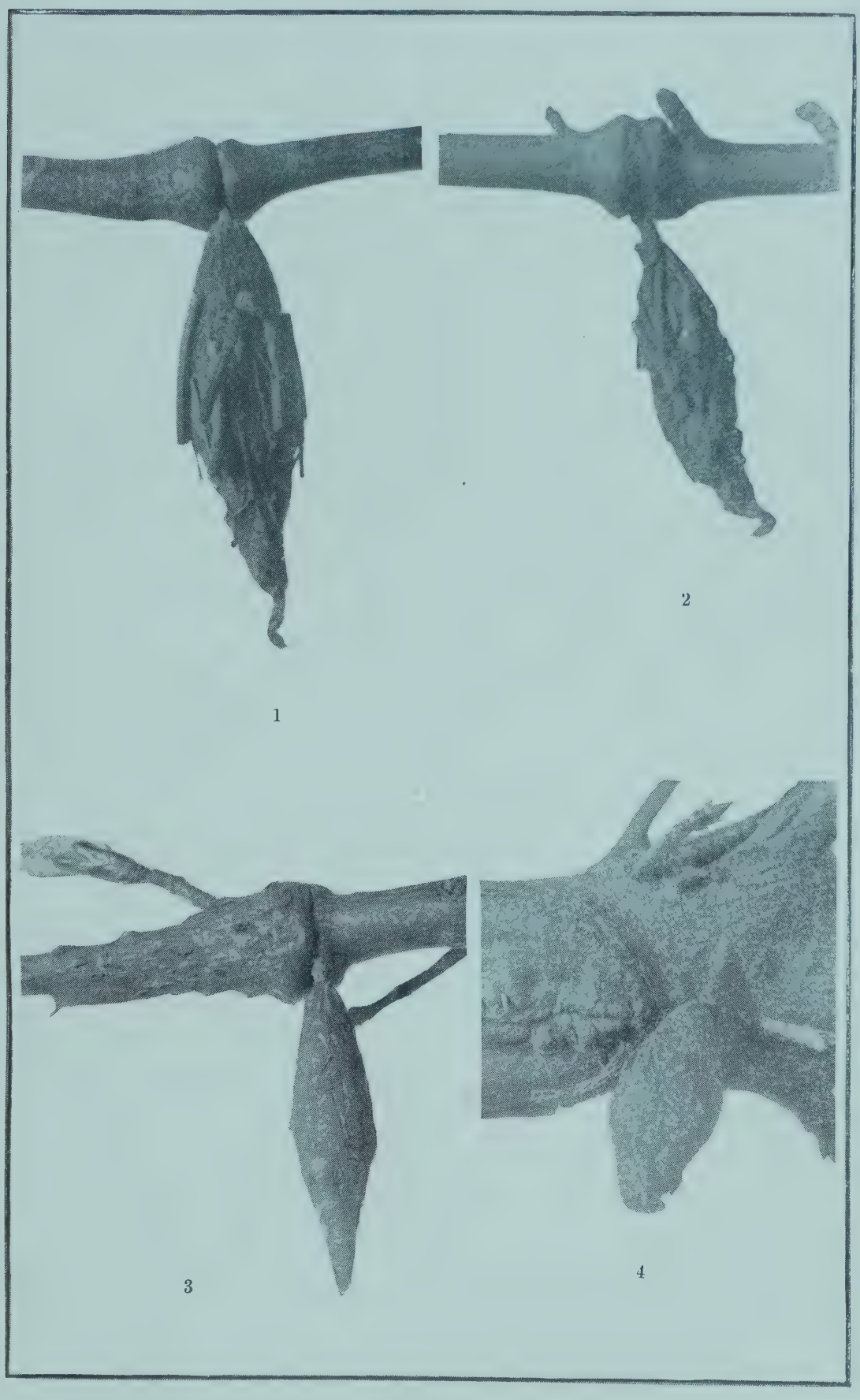
Table II. — Showing a number of exceptionally strong bands, their dimensions and the trees they were found on. (P. 178).



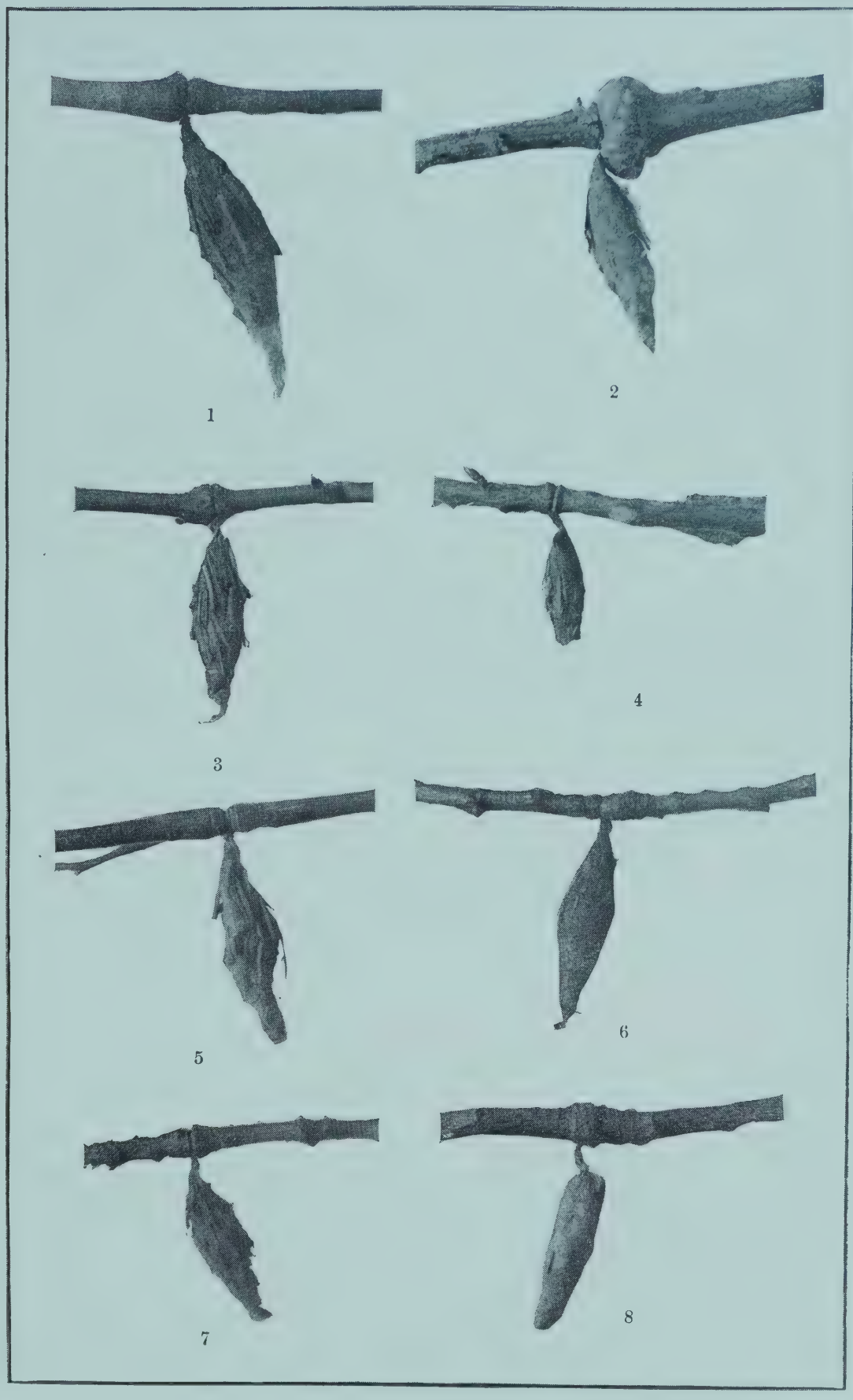
CONSTRICTIONS OF ARBOR VITAE.



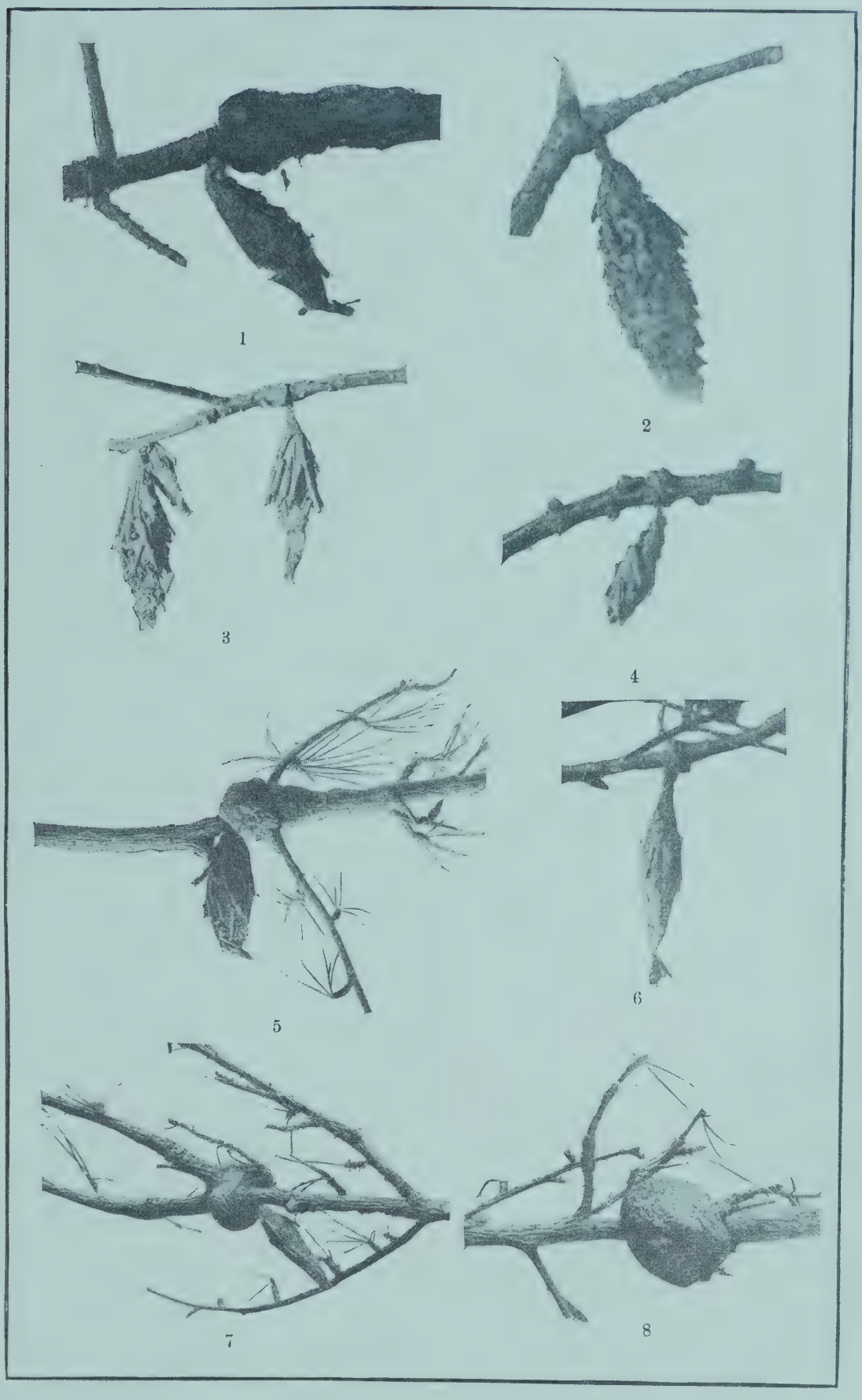
BAG WORMS—FIRST YEAR.



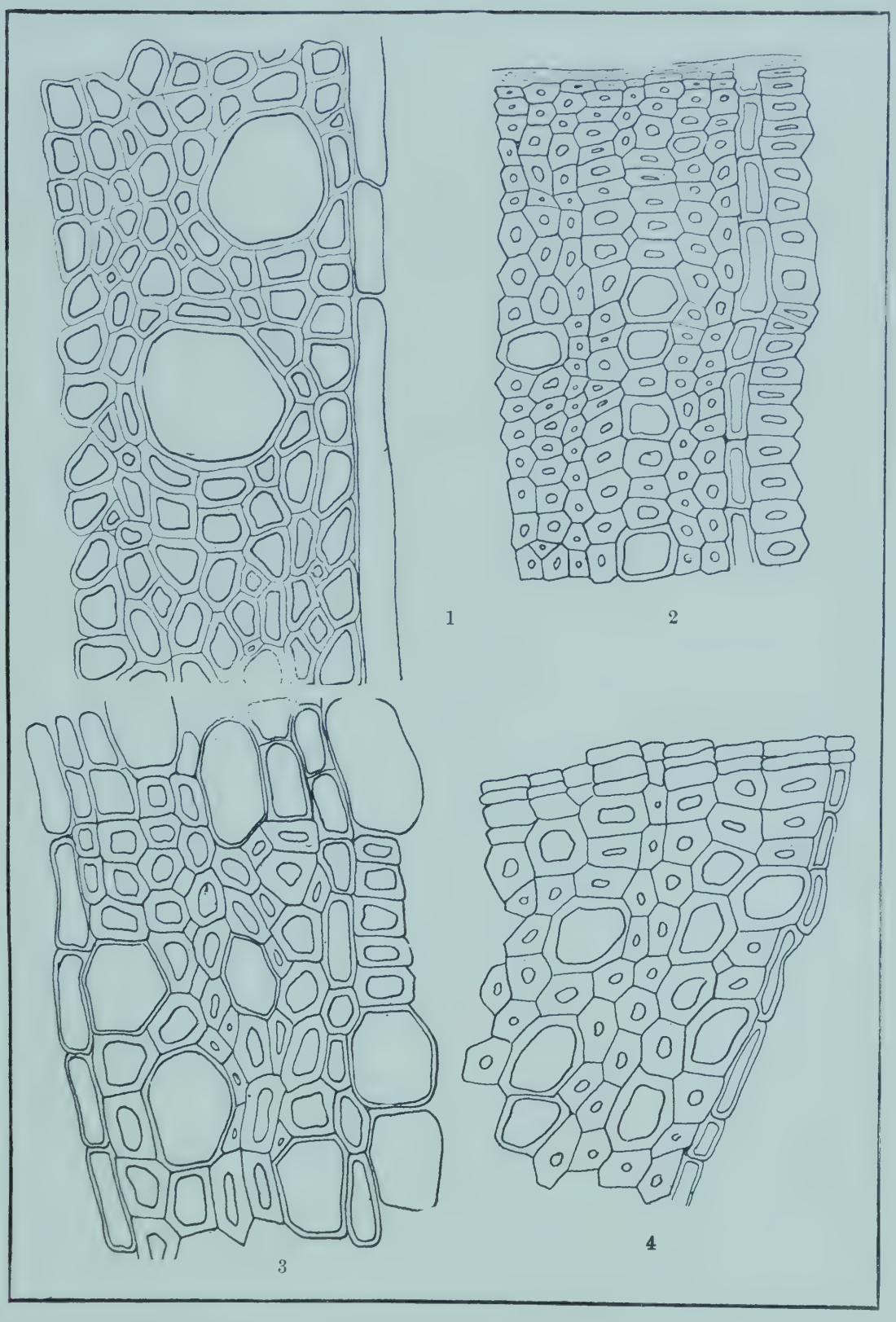
CONSTRICTIONS OF SOFT MAPLE.



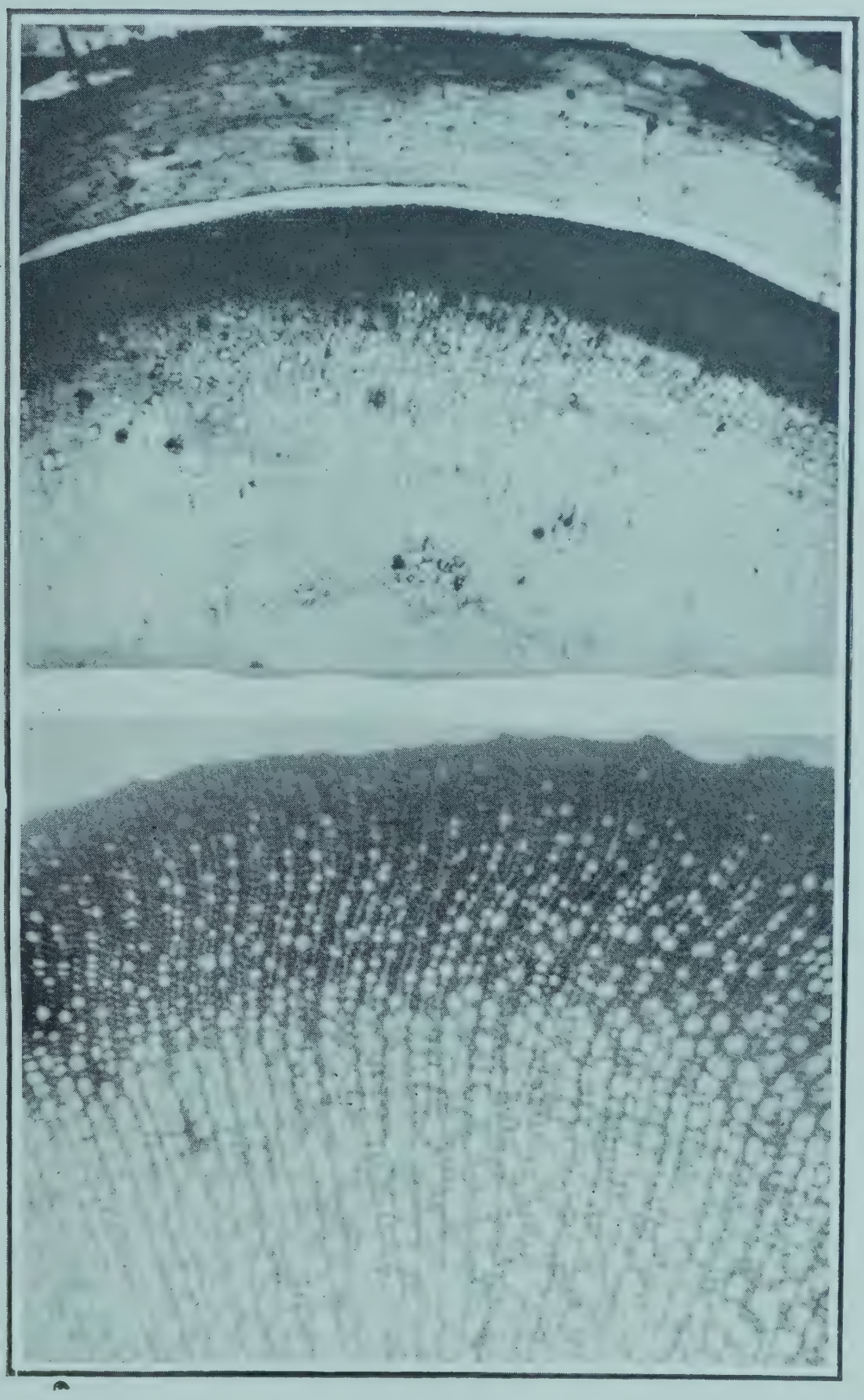
CONSTRICTIONS OF HARDWOODS.



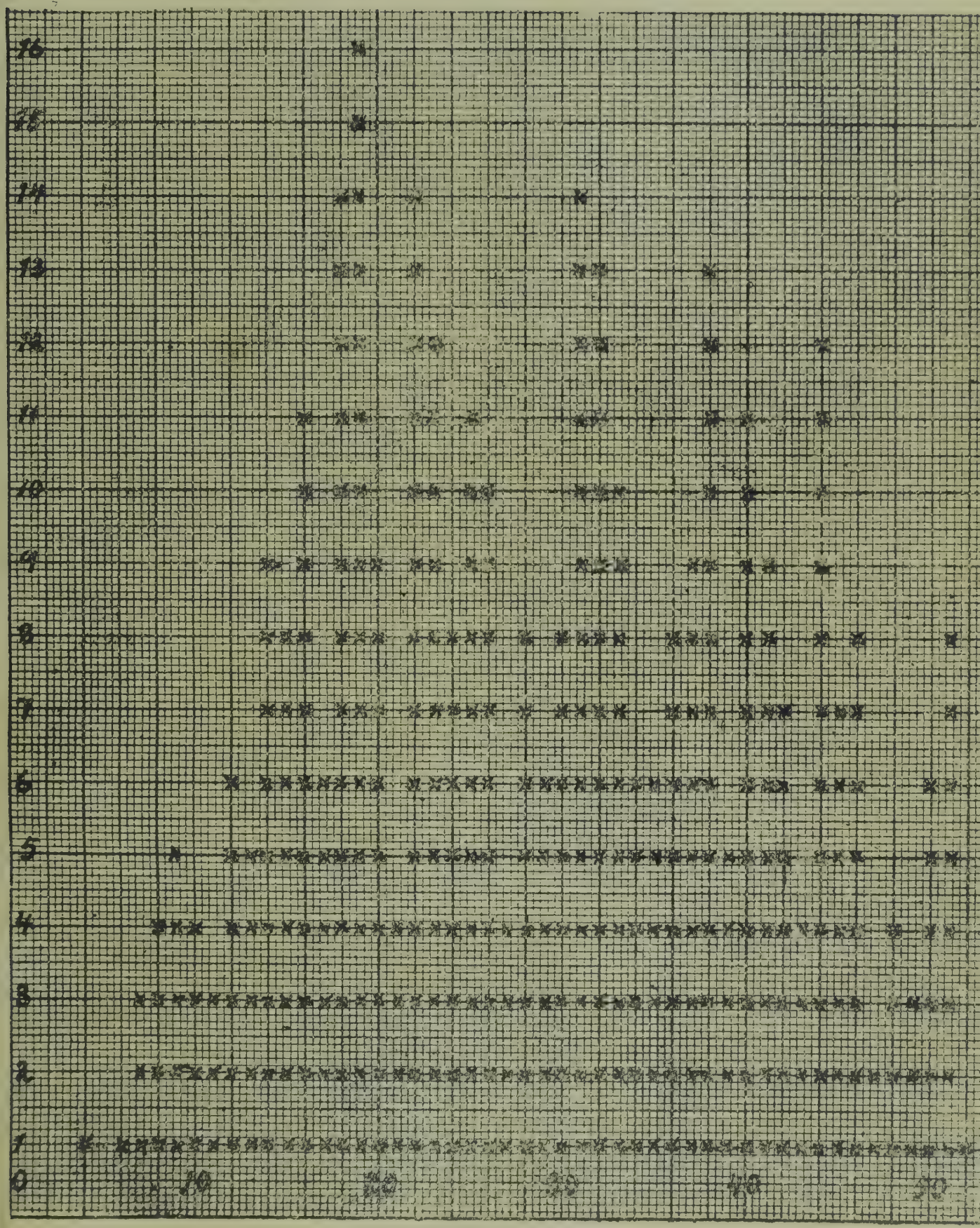
CONSTRICTIONS OF CONIFERS.



NORMAL AND CONSTRICTED WOOD.



WOOD BELOW BANDS.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